Pacific Fisheries Resource Conservation Council

BACKGROUND PAPER NO. 2000/2

Review of the Coho and Chinook Salmon Sections of the

"Agreement Under the *Pacific Salmon Treaty*" between Canada and the United States, dated 30 June 1999

by

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1. Executive Summary

This report reviews the June 1999 "Agreement Under the *Pacific Salmon Treaty*" between Canada and the United States, simply referred to here as "the Agreement." The terms of reference from the Pacific Fisheries Resource Conservation Council (PFRCC) particularly focused this review on how adequately the Aggregate Abundance-Based Management (AABM) rules specified in the Agreement deal with conservation issues for Canadian coho and chinook salmon.

Our evaluation focused on two general areas: the objectives of the Agreement, and the ability of its management rules to achieve those objectives. We evaluated the objectives in a broad context of conservation concerns and international standards, which are currently undergoing rapid development. Our evaluation of the rules is necessarily limited because many of the details for implementing the Agreement are yet to be worked out, especially those for coho salmon. Moreover, detailed data for wild Canadian chinook and coho stocks are limited due to various logistical constraints. Therefore, most of our analysis of the rules deals with chinook and relies partly on assumptions that are meant to roughly represent typical situations. The Agreement states that the intention is to develop similar rules for coho. Thus, most of our comments on chinook are at least generally applicable to coho.

This review points out, from a conservation point of view, positive aspects of the Agreement and provides constructive criticism in the form of 15 recommendations where the Agreement appears to be inadequate. These recommendations may assist the Chinook and Coho Technical Committees of the Pacific Salmon Commission (PSC) as they work out details for implementing the Agreement over the coming months and years. As well, the recommendations might provide a useful basis for discussion when the Agreement is renegotiated in the future.

THE AGREEMENT'S OBJECTIVES

The Agreement's chief objectives are to:

- achieve maximum sustainable harvest or optimum production;
- rebuild naturally reproducing stocks;
- halt the decline in spawning escapements in depressed stocks; and
- maintain genetic and ecological diversity of Pacific salmon.

THE AGREEMENT'S AABM RULES FOR MANAGEMENT

The Agreement sets out AABM regimes for chinook populations. The AABM rules apply to: Southeast Alaska troll, net, and sport fisheries; Northern British Columbia troll and Queen Charlotte Islands sport fisheries; and the West Coast of Vancouver Island troll and outside sport fisheries. These fisheries harvest stocks that originate from a wide variety of areas.

The Agreement specifies that target catches in these AABM fisheries should decrease when abundance in those fishing areas declines. In addition, the AABM regimes set out complex rules for further specified reductions in target catch in response to decreases in spawner abundance. Because of limited data and because many stocks and "stock groups" are managed together in an AABM fishery, indicators of spawner abundance are necessarily defined as aggregates, or sums, of escapements for a small number of selected "indicator" stocks. Additional reductions in AABM target catches are triggered only when low aggregate escapement exists for the indicator stocks in two consecutive years, and in two or more "stock groups" simultaneously.

HOW WELL DOES THE AGREEMENT ADDRESS CONSERVATION CONCERNS?

To define a context for our evaluation of the Agreement, we compared it with an ideal management system, from the point of view of conservation. Such a system would include:

- well-defined objectives for harvest, conservation, and biodiversity;
- effective indicators of abundance and productivity;
- pre-specified adjustments to harvest in response to those indicators, so as to prevent conservation concerns from developing, as well as to ensure prompt response when they do occur;
- effective monitoring and control of exploitation rates; and
- harvest rules that take uncertainty and variability into account.

We found that the Agreement is a positive step forward in several respects. First, it creates a formal procedure for changing target catches based on either pre-season or in-season estimates of adult salmon abundance. As those estimates of abundance decrease, so will target catch. The fact that the change in target catches has been agreed upon in advance of fishing seasons is a strong point. This will help avoid the problems caused by unfinished negotiations that have plagued Canadian and US salmon fisheries in recent years. A second positive aspect of these new target catches is that, if the AABM rules had been applied previously, they would have substantially reduced chinook exploitation rates in the 1979-1982 "base period" used by the PSC for many of its comparisons, as well as for many years afterwards. Third, the Agreement also establishes mechanisms for further reducing chinook target catches by prescribed amounts in response to low escapements of certain stocks. Fourth, in spite of its shortcomings described later, the Agreement at least creates a framework for implementing future improvements that could more adequately address conservation concerns for salmon.

Despite these positive aspects of the Agreement, our analyses suggest some drawbacks. The general approach of reducing target catch in response to decreasing abundance of stocks is appropriate. However, it is questionable whether or not the magnitude of reduction in catch in the Agreement's rules is sufficient to adequately maintain some Canadian chinook salmon stocks that are of concern from a conservation point of view, let alone rebuild them in a reasonable time.

Our simulations of the Agreement's AABM management regimes shed light on reasons for these shortcomings. Target catch decreases relatively little as the chinook abundance index decreases and will thus not necessarily allow stocks to maintain themselves, let alone rebuild, when abundances are low or survival rates are poor. Also, the specified additional reduction in target catches (which is to be implemented if certain "indicator" stocks fall below some designated spawner abundance) is not likely to be triggered frequently enough when needed, and when it is implemented, the reduction may be insufficient to promote rebuilding or sustain abundance. In addition, the "indicator" stocks used to trigger that additional reduction may not adequately reflect conditions for other salmon stocks that have lower productivities.

This insufficient treatment of conservation issues by the Agreement partly reflects its lack of both ***detailed*** management objectives that relate to conservation and effective indicators of how well any given set of harvest regulations meets those objectives. While the Agreement includes goals that are oriented towards conservation, they are quite general (e.g., "...rebuild naturally reproducing stocks and sustain them at optimum production," "...prevent further decline in spawning escapements" and "...maintain genetic and ecological diversity"). Unfortunately, the Agreement provides little guidance about specific definitions of the conservation objectives, especially the last one, or how these might be measured. In contrast, the Agreement frequently refers to maximim sustainable yield (MSY) objectives (i.e., moving spawning populations to the level where each will produce the maximum annual sustainable yield or harvest).

To be fair, the insufficiently detailed conservation objectives and indicators in the Agreement result at least in part from the current limited state of knowledge for many BC salmon stocks concerning what constitutes appropriate conservation units. We realize that extensive discussions are occurring at present within the Department of Fisheries and Oceans on this topic. Nevertheless, we have been asked to determine how well the rules written in the Agreement address the PFRCC's current conservation concerns.

WHAT CHANGES MIGHT ALLOW THE RULES TO BETTER ACHIEVE THE OBJECTIVES?

One of our recommendations is that considerable effort be put into identifying, and putting into the Agreement, clearer definitions of conservation goals. They should include clear and defensible spatial units of concern, measurable targets, and a time frame for reaching the goals. Management agencies should be provided with sufficient funds to collect data at the appropriate spatial scale and intensity to estimate directly how well those goals are being met. We also suggest modifying the Agreement so that target catches decrease more rapidly with decreasing abundance indices. As well, indicator stocks that trigger additional reductions in target catches should reflect conditions of those stocks that are most at risk. Furthermore, quantitative simulations should be done to identify appropriate "limit reference points" (low abundance that should be avoided) and related, but higher, reference points that will trigger pre-defined reductions in target catches to decrease the chance that certain stocks will even approach, let alone cross, their "limit reference points." Such analyses will thus help meet conservation goals by being proactive (aiming to avoid even coming close to low-abundance limit reference points), as well as reactive (using pre-defined actions to reverse a downward trend).

DOES THE AGREEMENT REFLECT INTERNATIONAL STANDARDS FOR FISHERIES MANAGEMENT?

Internationally recognized United Nations documents ("Precautionary Approach to Capture Fisheries," "Code of Conduct for Responsible Fisheries," and the 1995 United Nations Agreement on Straddling Fish Stocks and Highly Migratory Fish Stocks) emphasize a ***precautionary*** approach to fisheries management, which should include provisions for:

- allowing stocks to recover before increasing harvests;
- adopting objectives other than maximum sustained yield;
- timely and adequate response to decreasing productivity or abundance;
- avoidance of artificial propagation as a substitute for vigorous wild populations;
- stock-specific reference points designed to avoid low abundance; and
- explicit consideration of risks, uncertainties, and variability.

This last point is particularly critical for a precautionary approach to management. The greater the uncertainties are, the more harvests should be reduced in order to diminish conservation risks.

The current Agreement includes only some of these international standards. We recommend that the Agreement's objectives and rules be modified to include all of them.

2. Terms of Reference

At the request of the Pacific Fisheries Resource Conservation Council (PFRCC), we independently reviewed the "Agreement Under the *Pacific Salmon Treaty*" between Canada and the United States, dated 23 June 1999 (henceforth simply referred to as "the Agreement"). This Agreement is the 40-page document (plus eight pages of attachments) signed on 30 June 1999 by Donald McRae (Chief Negotiator for Canada) and James Pipkin (Chief Negotiator for the United States of America).

The terms of reference specified by the PFRCC for our independent review were to examine the Agreement, "...with particular attention to the AABM (Aggregate Abundance-Based Management) rules for coho and chinook salmon, and prepare a report for the PFRCC providing a professional assessment on the following questions:

1. Do the AABM rules as presented provide for an adequately risk averse, precautionary approach to management of chinook and coho salmon, keeping in mind Canada's commitment to biodiversity and maintenance of productive salmon populations?

2. Do the rules create risks for maintenance of biodiversity, in particular are there reasonable or probable abundance/survival scenarios (differential patterns of survival among stocks or stock aggregates) under which the rules would permit continued overfishing of any 'evolutionarily significant' stock units?

3. Under what survival patterns and/or enhancement regimes would the rules permit localized or regional overfishing?

4. Will the rules permit recovery/restoration of historical biodiversity, or even maintain the status quo in terms of relative stock contributions to overall productivity?"

Thus, although the Agreement covers other Pacific salmon species, our review focuses on issues related to biodiversity and conservation of Canadian chinook (*Oncorhynchus tshawytscha*) and coho (*O. kisutch*) salmon.

Our approach in this review is to point out positive aspects of the Agreement from a conservation viewpoint and to provide constructive criticism in the form of recommendations where the Agreement appears inadequate. These recommendations might be useful as the Chinook and Coho Technical Committees (CTCs) of the Pacific Salmon Commission work out details for implementing the Agreement over the next months and years. As well, the recommendations might provide a useful basis for discussion when the Agreement is renegotiated in the future.

In their cover letter, the negotiators of the Agreement note that, in addition to taking appropriate measures to regulate harvests, "...appropriate freshwater habitat must be protected or restored to allow for successful salmon migration, spawning and juvenile rearing." However, the Agreement only deals with harvest regulations and, thus, our review does not address any freshwater habitat issues.

3. Background

Before proceeding, it is important to review a few key ideas related to salmon conservation, population biology, and management. More detailed descriptions of these topics are found in PFRCC (1999a,b), Groot and Margolis (1991), Hilborn and Walters (1992), and Pearcy (1992).

As given in the Terms of Reference, the terms "maintenance of biodiversity" and "productive salmon populations" refer generally to maintaining genetically and ecologically diverse groups of wild salmon that are able to persist and that have the potential to produce sustainable harvests. In recent years, scientists, management agencies, and the public have recognized the importance of maintaining this variety, in part (but not solely) because it retains groups of fish that have adaptations to regional and local physical and biological conditions. Such biodiversity can also be a "source" for immigrants to recolonize nearby areas where abundance has been reduced. This diversity of salmon, whether at the population, subpopulation, or smaller level has enabled salmon to persist for many thousands of years in highly variable ocean and freshwater environments. This biodiversity is partly why salmon have been able to contribute considerable economic and social benefits over many generations.

Unfortunately, measures of conservation or biodiversity for Pacific salmon are difficult to define and have not yet been widely agreed upon (see Walters and Korman 1999 in PFRCC 1999b). Significant progress has been made toward defining the spatial units of interest for conservation (e.g., Wood and Holtby 1998), which suggest the appropriate scale of groups of salmon to conserve. However, as noted in PFRCC (1999a, p. 30), there are still many gaps in information relating to defining these conservation units. [For simplicity, we refer here to the widely used term ESU (Evolutionarily Significant Unit) for the unit of concern for conservation; that unit might be defined in some other way in the future by others, but it will not affect our general conclusions]. Nonetheless, the lack of a clear definition of conservation goals does not preclude evaluating the Agreement because we know qualitatively that once harvesting becomes intense enough, average abundance of salmon populations decreases along with genetic diversity. At extreme harvest rates (extreme defined in the context of how favourable freshwater and marine survival rates are), concerns about conserving biodiversity become prominent because of the greater chance of low abundance, or complete loss, of certain stocks. These qualitative trends are based on the following concepts.

The productivity of salmon stocks is normally measured by the number of adult recruits produced per parental spawner. Where recruits are estimated from totaling the adults caught and those that escape to spawn, the latter are referred to as "escapement". The larger the ratio of recruits to spawners, the higher the productivity, and the more recruits that can be harvested sustainably for a given number of spawners. [Note that we specifically use the term "productivity" in this context, which is ***not*** to be confused with "production" — the latter is often used by the Department of Fisheries and Oceans (DFO) to mean catch]. If the ratio of recruits per spawner is on average greater than 1.0, then harvest can be taken repeatedly from the recruits but enough fish must be left unharvested to maintain the spawning population.

A sustainable harvest rate must be adjusted in response to various objectives and conditions. For example, if the goal is to rebuild a low-abundance stock, then harvest should be lower than the harvest expected to maintain a constant abundance. Productivity of salmon stocks is determined, in part, by survival rates of offspring. These rates are affected by factors such as the available food supply, appropriate rearing habitat, number of competitors, and predator abundance. Therefore, when those survival rates change, for instance, due to altered ocean conditions or human-induced siltation of spawning areas, then harvest rates must also change in order to meet a given objective. Short-term variability in survival rates and the resulting productivity should be taken into account when setting harvest rates, as should longer-term trends or persistent shifts in productivity to some new level.

An important complication for proper management is that most salmon are harvested in mixed-stock fisheries, particularly in commercial troll and sport fisheries, such as the AABM fisheries in the Agreement. Mixed-stock fisheries refer to cases in which several salmon stocks migrate through an area together and are vulnerable to harvest at the same time, even though managers might want to harvest only particular stocks. While selective fishing methods are currently being encouraged and developed, they still cannot eliminate mixed-stock fisheries. If all salmon stocks were equally productive (i.e., same number of recruits per spawner) and equally abundant, then mixed-stock fisheries would not be such a problem. However, mixed-stock fisheries typically include some salmon stocks that have high productivity and some that are relatively unproductive, and some are much less abundant than others. In the presence of a given harvest rate, the stocks that are less productive and/or less abundant have reduced chances of persisting over some given period, let alone rebuilding, than the more productive stocks.

Thus, from the standpoint of biodiversity and conservation, the key problem created by mixed-stock fisheries is that, unless the proportional harvest rate (i.e., the proportion of recruits caught) is below the rate that is sustainable by the *least* productive stock, some stocks will decrease in abundance. If this continues for many years, some of those stocks will have a high probability of extinction, or at least a large chance that they will not contribute much to either future harvest or to recolonizing other surrounding low-abundance stocks. Therefore, in the *short term*, lower harvest rates will reduce catches, but will increase the chances of maintaining highly diverse groups of salmon, whereas higher harvest rates will tend to erode biodiversity. However, in the *long term*, maintaining a diverse set of stocks may improve the ability of these salmon to respond to environmental changes that could increase the chances of obtaining reasonable harvests in the face of such changes.

In recent years, fisheries management agencies around the world have begun to apply the concepts of *limit* and *target* reference points to recognize these risks and trade-offs involved with given management regulations (e.g., Smith et al. 1993). A reference point is an estimated value of some variable, such as abundance of spawners, catch or proportional harvest rate, each of which is estimated via an agreed-upon procedure and which reflects the state of the resource or the fishery. *Limit* reference points are conditions, such as low abundance, that are unacceptably dangerous and should not be approached. In contrast, *target* reference points represent reasonable goals or objectives for management that have considerably less risk than *limit* reference points (Caddy and Mahon 1995). Fishery management strategies should minimize the probability of crossing *limit* reference points. To do so, management strategies should include reference points that will trigger pre-defined actions to decrease the chance that stocks will even approach, let alone cross, their "limit reference points" (Caddy and Mahon 1995). Such action should be initiated immediately to facilitate recovery of the stock (FAO 1995b). In contrast, fishery management strategies should ensure that *target* reference points are not exceeded on average. The poorer the quality of the data, the farther a target reference point should be from the limit reference point.

In the context of chinook and coho salmon, one could identify reference points for catches or escapements. As described below, the Agreement does some of both; it states targets in terms of catches for a given index of abundance, but it also identifies reference points in terms of lower bounds on acceptable escapements for certain stocks below which additional reductions occur in target catch.

Based on this background, we evaluate the AABM rules in the Agreement. Among other questions, we ask whether the rules adequately reflect the diversity in productivity and abundance among salmon stocks in major mixed-stock fisheries, whether the reference points are appropriate, and whether the rules specify adequate responses to future changes in productivity over time and space. To illustrate some of our points, we draw extensive quotes from the Agreement. Page numbers cited here refer to the original signed Agreement and may differ from Web site versions of the Agreement.

4. Trends in BC Chinook and Coho Salmon Escapement

We first examined the Salmon Escapement Data System (SEDS) database to characterize trends in escapements for BC coho and chinook populations. This database contains annual (though often sporadic) estimates of spawner abundance from 1950 to 1997 for hundreds of rivers or tributaries populated by coho and chinook salmon. We screened the database for completeness of each spawning-site time series (abundance data across all the years), and gave equal weighting to each selected time series in a DFO Statistical Area (e.g., Statistical Areas 1 to 29 — see Appendix 1 for more details on these calculations). For coho, 737 of the 1515 stream sites had 20 or more years of data from 1950 to 1997. From these data, we generated an index of spawner abundance for each of the 29 Statistical Areas in BC. We did a similar analysis for chinook salmon. Of the 531 chinook sites, we selected the 241 sites with at least 15 years of data. Unfortunately, the quality (reliability) of any given escapement estimate in SEDS is not necessarily high due to unavoidable challenges of estimating a changing population over time in a complex environment with limited staff and time (e.g., Cousens et al. 1982). However, the statistics we have computed are extremely robust to such measurement errors so long as escapement estimates are not systematically biased over time in an extreme fashion.

For coho salmon, spawner abundances were relatively stable across Statistical Areas from 1950-70, but have declined dramatically since then (Fig. 1A). This figure shows the escapement trend for the 29 Statistical Areas combined. Unfortunately, this alarming decline in escapement is observed for most Statistical Areas. To characterize this, we computed the average escapement for each site over the period 1985-97 (time since the 1985 Treaty) and compared it with that site's average escapement over 1950-70. Fig. 1B shows the median value for the ratio of these averages within each Statistical Area. For example, for the 64 spawning sites of Statistical Area 2 (Queen Charlotte Islands), the median site had an average escapement over the 1985-97 period that was only 15% of the average during 1950-70, or an 85% decrease in average escapement between the two periods. Note that this is not the worst site for Statistical Area 2, but rather the median or 50th percentile ratio.

For chinook salmon, escapements across Statistical Areas show a decline similar to that for coho, although they have been more stable, and even increasing, since the early 1980s (Fig. 2A). For sites within each Statistical Area, the median ratio in average escapement between 1950-70 and 1985-97 shows less reduction in abundance than for coho; however, in 11 of 25 Statistical Areas, the median reduction was 60% or more (Fig. 2B). There are notable exceptions, such as middle and upper Fraser River chinook populations (Statistical Area 29), in which abundance has tended to increase over time, but such cases are the exception rather than the rule.

Figure 1A

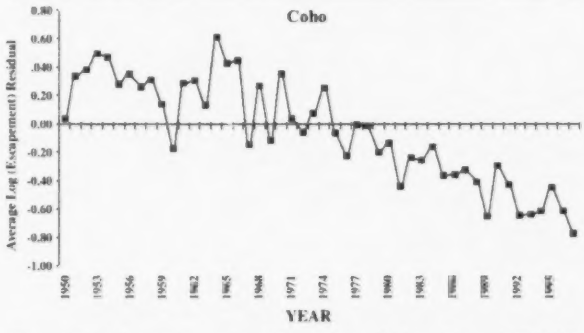


Figure 1A: Average natural logarithm of abundance of British Columbia coho salmon, averaged across all 29 Statistical Areas, standardized to each stream's mean abundance.

Figure 1B: Median Ratio of Average Coho Escapement (1985-97) to (1950-70) Esc.

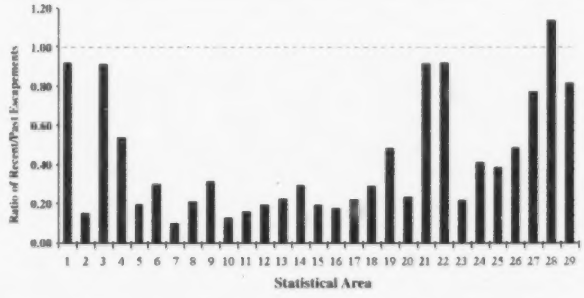


***Figure 1B**: Median ratio of average coho escapements for 1985-1997 to 1950-1970, by a given Statistical Area.*

Declines such as those illustrated in Fig. 1B are extremely worrisome from a conservation perspective. For the Ricker stock-recruitment relationship, for example, the spawner abundance that produces MSY is generally 30-45% of the unfished equilibrium spawner abundance (i.e., the average spawner abundance expected when there is no fishing). Thus, given that moderate to heavy fishing of BC coho and chinook populations occurred prior to and during the 1950-70 period, it is very worrisome that spawner abundances of numerous populations have declined up to 80% or more since then. Furthermore, the data also highlight the problem of "shifted baselines," which occurs if current objectives and goals are defined using recent data and trends, which may poorly reflect conditions of the more distant past (Pauly 1995). For BC chinook populations, as an example, the current escapement goals for many key natural stocks were derived by doubling the average spawner abundance observed from 1979-82 (CTC 1999). However, across Statistical Areas, escapements during 1979-82 were among the lowest since 1950 (Fig. 2A). Thus, the 1979-82 period may be a poor reference period upon which to base escapement goals.

Figure 2A

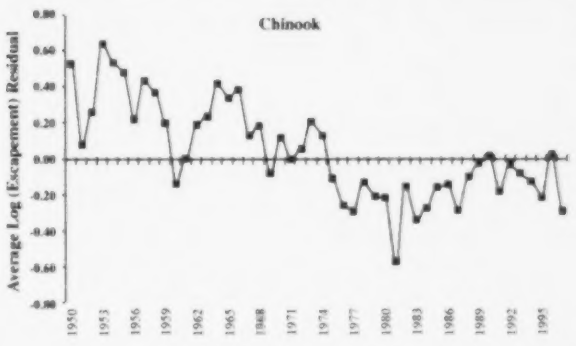


Figure 2B: Median Ratio of Average Chinook Escapement (1985-97) to (1950-70) Esc.

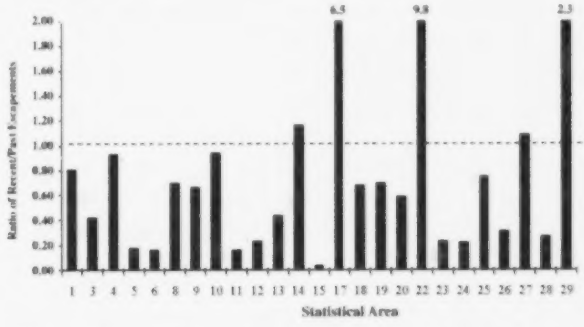


Figure 2: *Same as Figure 1, except for BC chinook salmon. Numbers above bars in Part B are the value on the Y axis for the respective Statistical Areas.*

5. The Rules for Aggregate Abundance-Based Management

The terms of reference for this review focus on evaluating the so-called Aggregate Abundance-Based Management (AABM) rules in the Agreement. These rules are defined in greatest detail in the chinook section, although the Agreement intends that similar rules will also be developed for coho salmon. The chinook section of the Agreement also identifies other rules that apply to fisheries (i.e., areas in which salmon are harvested by various types of gear) that are not covered under the AABM rules. These two types of rules are defined as follows (page 13, paragraph #2):

> "The Parties agree to implement, beginning in 1999 and extending through 2008, an abundance-based coastwide chinook management regime to meet the objectives set forth in paragraph 1 (a) above, under which fishery regimes shall be classified as aggregate abundance-based management regimes ("AABM") or individual stock-based management regimes ("ISBM"):
>
> (a) an AABM fishery is an abundance-based regime that constrains catch or total adult equivalent mortality to a numerical limit computed from either a pre-season forecast or an in-season estimate of abundance, and the application of a desired harvest rate index expressed as a proportion of the 1979-82 base period. The following regimes will be managed under an AABM regime:
>
> (i) southeast Alaska sport, net and troll;
> (ii) Northern British Columbia (NBC) troll ([DFO] statistical areas 1-5) and Queen Charlotte Islands (QCI) sport (statistical areas 1 and 2); and
> (iii) west coast of Vancouver Island (WCVI) troll (statistical areas 21, 23-27, and 121-127) and outside sport.
>
> (b) an ISBM fishery is an abundance-based regime that constrains to a numerical limit the total catch or the total adult equivalent mortality rate within the fisheries of a jurisdiction for a naturally spawning chinook stock or stock group. ISBM management regimes apply to all chinook fisheries subject to the Treaty that are not AABM fisheries."

Under the AABM rules, target catches for particular gear types in each of the above three large regions (Southeast Alaska [SEAK], Northern BC and Queen Charlotte Islands [NBC], and West Coast Vancouver Island [WCVI]) are made a function of an index of abundance, such that catch would decrease as the abundance index decreases (Fig. 3A). The "abundance index" is a standard term used by the Pacific Salmon Commission to estimate the number of fish available to be harvested in a region. Note that these target catches include catches of all stocks in each of the three large regions, regardless of their area of origin.

In addition, the AABM rules establish criteria (pp. 21-25) under which the target catches in Fig. 3A must be further reduced by a specified amount (p. 18) (referred to in our review as "adjustments to target catches"). For example, such adjustments will be implemented in the SEAK troll, net, and sport fisheries if ***spawner*** abundance of the WCVI fall chinook "stock group" ***and*** at least one other "stock group" falls too low, which is defined in a complex manner as follows. The Agreement defines seven "escapement indicator stocks" for the WCVI "stock group," the Artlish, Burman, Gold, Kauok, Tahsis, Tashish, and Marble Rivers. The sum of spawning escapements across these seven indicator stocks has an acceptable "lower bound," which is currently defined as the escapement that would result in an annual sustainable harvest 15% lower than the maximum sustainable harvest. [It can be shown that for many typical salmon stocks this is roughly equivalent to a spawning population about 50-60% of the abundance that produces MSY]. When the total escapement summed across all seven of these indicator stocks is less than this lower bound for ***two consecutive years***, then the reductions in target catches specified on page 18 of the Agreement will be triggered. ***But this is only if at least one other stock group*** (e.g., Upper Straight of Georgia, North/Central BC, etc. as listed on p. 21) that is caught in SEAK ***also meets that criterion*** of falling below its lower bound of escapement range in those same two consecutive years. The more

Figure 3A, B, C and D

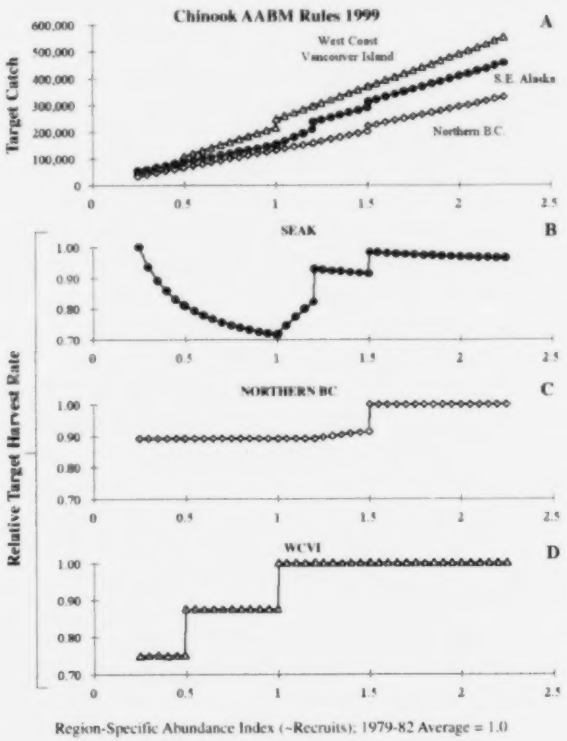


***Figure 3A**: Chinook target catch in the 1999 Agreement's AABM fisheries as a function of each region's abundance index (i.e., fish available to harvest); index = 1.0 is the 1979-1982 average abundance index for that region.*

***Figures 3B, 3C, and 3D**: Relative proportional harvest rates resulting from target catch functions in Part A. Each region's harvest rates are scaled to a relative maximum of 1.0. Because absolute chinook abundances are not known, these are only* relative *measures of proportional harvest rates.*

Figure 4

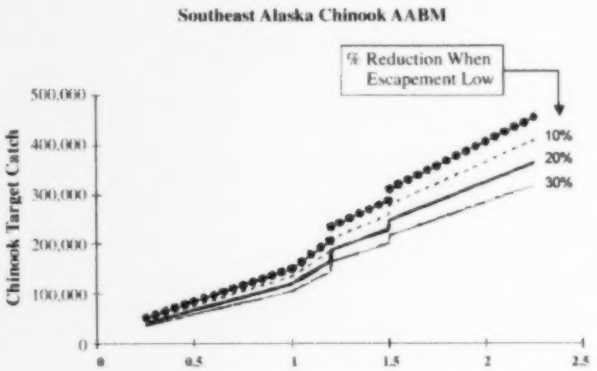


***Figure 4:** AABM adjustments to target catch in response to escapements in chinook indicator stocks dropping too low. This example is for Southeast Alaska chinook troll, net, and sport fisheries. Solid dots reflect unadjusted target catches.*

stock groups that meet their criteria for low abundance, the greater the reduction in target catches for a given AABM fishery. Specifically, if two stock groups meet the criteria stated above of escapement being too low, then the *target catch* for a given abundance index is reduced by 10%. If three stock groups meet the criteria, the target is reduced by 20%; and, if four or more stock groups are too low, the target catch is reduced by 30% (Fig. 4).

There is also a clause (Chapter three, paragraphs 2bii [p. 14], 4ei [p. 15]), that would permit "...additional reductions as necessary to meet the agreed escapement objectives," but as noted above, the Agreement does not specify those other objectives, let alone how to determine what reductions in catch are needed.

The Agreement specifies that similar rules will be developed in the future for coho salmon by the Coho Technical Committee, but does not provide any details.

6. Evaluation of the Agreement

The Canadian government should be commended for reaching this new agreement with the United States on management of Pacific salmon. It makes several significant advancements from the previous agreement under the *Pacific Salmon Treaty* with respect to conservation-oriented management of chinook and coho salmon. These include:

1. implementation of abundance-based management regimes in which catches of chinook and coho salmon are set annually and can be adjusted during fishing seasons with the intent of achieving prescribed exploitation rates, as opposed to the previous fixed ceilings for total catch;

2. mechanisms for further reducing catches by prescribed levels in AABM and ISBM fisheries in response to declining escapements of certain stocks;

3. for chinook salmon, substantial reductions in implied proportional exploitation rates for AABM and ISBM fisheries *relative* to the "base period" (1979-82) that has traditionally been used as the basis for comparison;

4. formal pre-season planning for both AABM and ISBM fisheries; and

5. pre-specified provisions for adjusting harvest regulations, which avoids delaying action within a fishing season.

The Agreement is, of course, not perfect. Although we discuss its shortcomings below, it is important to recognize that the Agreement is a substantial improvement over previous years when there was no agreement. Moreover, this Agreement creates a valuable framework for making future improvements to regulations that could more adequately address conservation concerns for salmon.

While the general approach of changing target catches in response to changes in estimated abundance is commendable, we question whether the Agreement's rules will adequately maintain or rebuild weak Canadian salmon stocks in a reasonable time. As we describe below, the main problem is that target catches decrease relatively little as salmon abundance decreases and will thus not necessarily benefit many low-abundance and/or low-productivity stocks. Also, the specified additional reduction in target catches is not likely to occur frequently, and the situation could be extremely serious for some stocks. This is because indicator stocks that trigger that additional reduction may not adequately reflect conditions for other salmon stocks that are of concern for conservation reasons.

This inadequate treatment of conservation issues by the Agreement partly reflects its lack of both *detailed* management objectives that relate to conservation and effective indicators of progress towards those objectives under any given set of management regulations (see details below). These insufficiently detailed conservation objectives and indicators result, at least partly, from the current state of knowledge about many BC salmon stocks. As stated in PFRCC (1999a, p. 37), there is a paucity of complete population data on many salmon stocks, making it difficult to meet objectives related to their conservation. As well, the Agreement was negotiated over a lengthy period during the 1990s when the priority placed on salmon conservation by the public and government changed dramatically. Conservation of West Coast salmon became a significant public concern after the Fraser River Sockeye Public Review Board's (1995) report on the 1994 "missing sockeye salmon" situation on the Fraser River. In this context, it is perhaps unfair to judge the Agreement against criteria that were not prominent during most of the negotiations and that were still being debated and clarified by scientists and managers at the time. Nevertheless, it is legitimate to ask how well the Agreement will address current conservation concerns for salmon and what aspects of the Agreement should be changed to better meet that goal.

We evaluated the Agreement in three ways:

1. qualitative judgments of the Agreement;

2. quantitative evaluations of the proposed "Aggregate Abundance-Based Management" rules, using selected chinook salmon stocks as an example; and

3. comparison of the Agreement with some international documents on fisheries management, including the 1995 United Nations Agreement on Straddling Fish Stocks and Highly Migratory Fish Stocks which both Canada and the US signed.

Our evaluation was somewhat limited because many critical aspects for implementing the Agreement were vague at the time of writing this review — details are yet to be worked out by the Chinook and Coho Technical Committees (composed of US and Canadian scientists). The rules for coho are particularly general and preliminary. This vagueness of the Agreement also emphasizes that, although it reflects the best of intentions, some future members of the technical committees might not benefit from the legacy of first-hand experience of those who did technical analyses in support of the Agreement as it was being negotiated. This is a concern because the success of the Agreement at achieving its goals to halt the decline of abundance and rebuild naturally producing salmon stocks will depend heavily on how several aspects of the Agreement are implemented.

Recommendation # 1:
We strongly recommend clear documentation and ready availability of information as details for implementing the Agreement are worked out by the Chinook and Coho Technical Committees.

CHARACTERISTICS OF AN IDEAL MANAGEMENT SYSTEM

We also evaluated the Agreement in terms of six characteristics of an ideal salmon management system designed to simultaneously meet the objectives specified in the terms of reference for this review: conservation, biodiversity, and harvests. Such a salmon management system should contain the following key elements:

a) Explicit definitions of objectives for conservation, biodiversity, and harvest.

b) Effective and measurable indicators of catch and spawner abundances for certain salmon stocks that directly reflect those objectives.

c) Pre-specified rules that set and adjust harvests sufficiently as the abundance, productivity, or other conditions of salmon stocks change across years or within seasons; those rules should be primarily *proactive* and aim to reduce the chance that stocks will become a conservation concern. However, rules should also be *reactive*, eliciting a prompt and appropriate response if stocks do enter that region of concern.

d) Effective monitoring, control, and enforcement of exploitation rates of all fisheries with the potential to rapidly reduce exploitation rates to the extent necessary.

e) Harvest rules that take into account uncertainties in factors such as survival rates of fish stocks, estimates of abundance, and realized (as opposed to intended) exploitation rates.

These are the minimum requirements for management regimes to achieve the goals stated in the terms of reference for this review, namely to be "adequately risk averse" and to take a "precautionary approach."

We now evaluate the Agreement in terms of how well it reflects these five characteristics of an ideal management system. We do not expect that any agreement will be "ideal," but these characteristics provide a standard against which we can evaluate it.

A. Definitions of objectives

We noted in Chapter 3 that maintaining biodiversity is an important component of an overall strategy for having salmon populations that can produce sustainable harvests, especially in the face of uncertain future changes in freshwater and marine habitats. Including clear conservation objectives or goals in the Agreement, along with appropriate management actions to meet them, would thus minimize losses in biodiversity, reduce the potential for costly closures of fisheries, and potentially improve future catches.

An Ideal Management Objective

What would an ideal conservation-oriented goal or objective look like? A good example is the goal for rebuilding Snake River chinook salmon in the US. A 1994 US National Marine Fisheries Service "Biological Requirements Working Group" set threshold escapement goals (numbers of spawners) for each of seven index stocks that were "listed" under the Endangered Species Act (BRWG 1994). The working group specified that in order for the rebuilding objective to be met by some proposed management action, 80% of those stocks (i.e., about six out of the seven) must have a high probability of being above their respective escapement thresholds (during the next 24 years in one case, and 100 years in another), as determined by a stochastic simulation model. For simplicity, results of analyses were eventually reported for the sixth-best stock of those seven.

This example for Snake River chinook is instructive because it illustrates four important features of management goals. First, it contains an explicit, measurable "target reference point" (escapement level) that will indicate when the goal has been met and how close the goal is to being met currently. Second, it specifies the management unit that must reach the target reference point, in this case, six out of the seven individual stocks. Setting escapement goals in terms of the sixth-best stock reflects the variability in productivity and current abundance among the stocks. Third, this Snake River example stipulates a time by which the target reference point should be achieved. Finally, it recognizes that evaluations of management options for meeting the goal involve unavoidable uncertainties and, hence, it states that the action should have a "high probability" of achieving the goal (later interpreted by US scientists to mean at least a 70% chance).

The Agreement's Objectives

Here we compare these four features of an ideal management goal with some examples of the stated goals of the 1999 Canada-US Agreement:

1. "...to regulate the harvest of salmon in order to rebuild naturally reproducing stocks and sustain them at optimum production" (p. 2 of the cover letter signed by the two negotiators);

2. to establish a chinook management program that: "... halts the decline in spawning escapements in depressed chinook salmon stocks, sustains healthy stocks and rebuilds stocks that have yet to achieve MSY or other biologically-based escapement objectives" (p. 12);

3. for coho, it similarly intends to "...prevent further decline in spawning escapements..." (p. 31); and

4. "...achiev[e] maximum sustainable harvest for a set of agreed key natural stock management units while maintaining genetic and ecological diversity... and... promot[ing] rebuilding" (p. 33).

Essentially, the Agreement's goals are to stop the decline in spawning escapements of depressed chinook and coho salmon stocks and rebuild them to some higher level (referred to here as the rebuilding goal), as well as maintain genetic and ecological diversity (the biodiversity goal). Some of these objectives are relatively clear, such as halting the decline in spawner abundance. However, others appear to point in the right direction, but are incompletely specified in comparison to the Snake River example.

We looked for these features: (1) a clear, measurable target reference point; (2) a clearly defined management unit of concern; (3) a time frame for reaching the goal; and (4) some recognition of uncertainty in reaching the goal.

For the Agreement's *rebuilding goal*, these features are as follows: (1) In several places, the Agreement clearly states a target reference point of a spawning population that will generate the maximum sustainable yield (MSY). In other places, it refers to "optimum production" (not defined), or "other biologically-based escapement objectives" (again, not defined). (2) The management unit of concern for rebuilding can only be inferred indirectly from statements in the Agreement. One could interpret them to mean *all* wild stocks that are below their MSY escapement

or the other, yet-to-be-defined escapement objectives. However, the lack of stock-specific data on hundreds of chinook and coho stocks precludes estimating stock-specific MSY escapement goals for most stocks. Hence, in practice, the Agreement's target reference points likely apply to much larger groupings of stocks. It thus appears that the management units for rebuilding chinook salmon are the Agreement's "stock groups" (e.g., West Coast Vancouver Island fall chinook, North/Central BC chinook, and Upper Georgia Strait chinook). Each of these stock groups is composed of a large number of stocks, reflected by between three and seven indicator stocks. (3) The Agreement does not state the date by when the target should be met. The Agreement expires for chinook in 2008, but that would be a very optimistic time frame because it would only allow fish populations to increase over about two generations. (4) The Agreement's stated objectives do not reflect the uncertainties associated with achieving them on only some stocks.

Similarly, the Agreement's *biodiversity goals* are incompletely specified, as defined by the four features of an ideal goal: (1) There is no stated target reference point (in terms of a measure of genetic or ecological diversity). (2) The Agreement does not explicitly define the management unit for biodiversity (e.g., Evolutionarily Significant Unit, or ESU) of salmon that should be conserved. However, as explained below, we infer from the way that the Agreement's AABM rules are set up that the ESUs are the large "stock groups" as defined above. (3) For *maintaining* biodiversity, it is perhaps not necessary to give a time frame because the goal implies that it aims to keep biodiversity, however measured, at its current level. (4) This biodiversity goal does not state any uncertainty about how many stock groups should achieve it.

In short, because of the lack of detail, many goals or objectives of the Agreement do not pass the "clarity test" of Morgan and Henrion (1990, p. 50). In other words, they are not sufficiently well specified that a group of knowledgeable people, given a description of the issue, could agree whether the goal had been met (e.g., rebuilding or maintaining genetic and ecological diversity). Without such precision, vagueness about what the goal represents is liable to get confounded with uncertainty about whether it was achieved.

Recommendation # 2:
Given that explicit goals or objectives are necessary before management strategies can be identified for achieving them, the Agreement needs clearer definitions for goals, especially those intended to directly reflect concerns about conservation and biodiversity. Each goal should have a clear, measurable target reference point, a clearly defined management unit, a time frame for reaching the goal, and some recognition of uncertainty in reaching the goal.

B. Indicators to Reflect Objectives

Because of the lack of details about the Agreement's conservation objectives, it is critical to review its indicators, which either directly or indirectly reflect two important features of those objectives: management units and target reference points.

At the outset it is important to realize the constraints on the Agreement created by limited data. Catches *by stock* for most of the hundreds of individual *wild* populations are not known precisely due to logistical constraints that prevent specific stock identification.

This shortcoming of catch data on small spatial scales also applies to data on abundance of spawners and recruits, and undoubtedly constrained the ability of negotiators and their staff to specify in the Agreement ideal indicators of its conservation goals. The reality of limited budgets for DFO hampers making reliable escapement and adult recruitment estimates on any, let alone most, of the several hundred chinook and coho stocks in BC. This hinders rigorously estimating escapement levels required to meet a given conservation objective, let alone an objective to move stocks to escapements that generate MSY.

Management Units and Evolutionarily Significant Units (ESUs)

The spatial scale at which the Agreement intends to maintain biodiversity or rebuild stocks is unclear. Scientists working on conservation issues generally accept that an important starting point for design of appropriate management regulations to deal with conservation concerns is a clear definition of ESUs and indicators that quantify risks for particular ESUs associated with any given management plan. For instance, given sufficient data, one could estimate the proportion of stocks within some region or ESU that are in danger of extinction. However, the Agreement did not explicitly define the spatial or stock units that need to be conserved, nor does it discuss monitoring that diversity. Moreover, while rebuilding of stocks to higher abundance appears on the surface to be consistent with conservation goals, the lack of explicit spatial or stock units for this objective is disconcerting. If the Agreement intends to rebuild all depressed stocks, including the *least* productive stocks, then genetic and ecological diversity will likely be maintained. However, as discussed below, the stock units and their measures of status implied by the Agreement do not appear to be based on sound conservation criteria and, thus, create a high chance of losing biodiversity.

While no ESUs were explicitly defined, the Agreement indirectly implies that the ESUs for Canadian chinook (i.e., groups of stocks that need to be conserved) are large "stock groups" such as North/Central BC chinook and West Coast Vancouver Island fall chinook. We drew this conclusion about the implied ESUs because the Agreement defines rules for adjusting AABM and ISBM catches that are determined by the status of each stock group. However, as discussed in more detail below, the measure of the status of a "stock group" is based on spawner abundances of a few indicator stocks. Our concern is that these indicator stocks may poorly reflect the condition of other stocks when that stock group covers a large and diverse geographic area, such as for North/Central BC chinook. In general, these stock groups defined for BC chinook seem inappropriately large in scale from a conservation perspective (e.g., Wood and Holtby 1998), and appear to be defined more on the basis of management logistics than on defensible biological criteria related to biodiversity. Likewise, for coho salmon, it is unclear if the yet-to-be-defined "key natural stock management units" will have appropriate spatial scales for managing biodiversity. For example, on page 32 of the Agreement, a list of only *eight* example "management units" is provided for southern BC, covering Statistical Areas 12 through 29. It is worth noting that for these areas, the SEDS database contains records for 771 separate sites for estimating coho salmon escapement.

We must emphasize that this lack of detail on ESUs in particular is not the fault of the negotiators of the Agreement or their staff because this topic was (and still is) a subject of considerable discussion among DFO scientists and managers. Scientists have limited data on abundance, movement of fish among streams, and genetic diversity of many stocks (PFRCC 1999a). It therefore has rarely been possible to define groups of stocks that should be preserved to meet this goal. However, given that reality, and if the general goal is to maintain biodiversity in the face of limited knowledge about how to measure it, then management strategies must take extra precautions. The Agreement did not explicitly recognize this point.

Recommendation # 3:
We recommend that DFO strongly support further efforts to define the appropriate spatial units for management and conservation of chinook and coho salmon.

How Well Do Indicator Stocks Reflect Conservation Concerns?

As noted above, the status of each "stock group" contributing to AABM (or ISBM) fisheries will be used to determine whether additional harvest reductions are required to meet escapement objectives. While DFO estimates spawner abundance for many small stocks, it is not routinely done as thoroughly as in the case of more abundant stocks. Instead, DFO has been forced to put more effort into monitoring a smaller number of "index" or "indicator" stocks, which are used in the Agreement to reflect the status of a "stock group" as a whole. The Agreement shows on pages 21-25 which indicator chinook stocks to use for deciding whether escapement is low enough to trigger an additional decrease in target catch (see Chapter 5 for details on how "adjustments" to AABM catch are triggered).

Thus, from the standpoint of conserving small, relatively unproductive stocks, there is a key question: Do the "indicator stocks" specified in the Agreement provide a good indicator of the status of other stocks in a given "stock group?" The Agreement does not state whether "indicator stocks" are meant to represent the most endangered stocks, or a diverse range of productivities, or just the most productive stocks. Thus, the answer to the question depends greatly on the extent to which spawner abundances of the indicator stocks correlate with spawner abundances of other stocks. If they are highly correlated, then declining abundance in indicator stocks that trigger the AABM rules' reduction in catch, or adjustments to it, will likely adequately protect the small, relatively unproductive stocks. However, if this is not the case, then situations could exist in which indicator stocks are stable or rebuilding, but other stocks do poorly and no reductions in harvest rates would occur.

As an example, we examined chinook escapement data for the NC (North/Central) stock group and found little evidence that the indicator stocks are "representative" of the stock group as a whole. Escapement data and rebuilding efforts from 1977 to 1996 for all BC chinook indicator stocks are documented in CTC (1999). For the NC stock group (Statistical Areas 1-10), current escapements of the three indicator stocks (Yakoun, Skeena, and Nass) are near or above their respective goals and represent positive rebuilding since the base period 1979-82. However, other index sites for this region are discussed in CTC (1999) but are *not* included in the Agreement. They are: Statistical Area 6 (showed extremely low escapements in recent years); the Dean River in Statistical Area 8 (classified as "Not Rebuilding" and appears to be worsening over time); and Smith Inlet (dropped from CTC assessment due to monitoring difficulties, as was Area 6, but also showed extremely low escapements in recent years). So while improvements have been seen for Nass, Skeena, and Yakoun chinook, it appears that other stocks do not show signs of rebuilding and, in some cases, show apparent declines. Furthermore, the NC stock group covers a large geographical area with no representation south of Area 4 within the Agreement. Hence, we question how well the Nass, Skeena, and Yakoun indices represent other stocks in this region.

In summary, it appears that the current use of "indicator" stocks may be inadequate from a conservation perspective for some BC chinook stock groups. There is a potentially large chance that some stocks within a stock group could decline in abundance without any action being required in terms of reducing AABM (or ISBM) harvests.

Recommendation # 4:
Where possible, we recommend choosing indicator stocks that are more representative of stocks that may be at risk. If this is not possible, then harvest rules should be made more cautious to reflect this lack of representation.

Target and Limit Reference Points

The Agreement frequently mentions escapement goals that will produce the maximum sustainable yield (MSY), but it is well known that this is *not* a desirable target reference point from a conservation point of view, although it may be appropriate for productive, high-abundance stocks (FAO 1994). Past research has shown that biological risks are greater for a population with its average escapement at the MSY escapement level rather than at a larger abundance. These higher risks result from natural variability in survival rates from year to year and imperfect information, both of which increase the chances that realized harvests might be considerably higher than desired. To its credit, in many other places, the Agreement states that the goal for spawner abundance should be "...MSY or other agreed biologically based escapement objectives" (e.g., p. 12). However, while those "other" objectives might be more conservation-oriented, there is no guarantee that they will be, nor is there any statement forcing agreement on such objectives.

Furthermore, as noted above, the limited stock-specific data on numerous chinook and coho salmon stocks also hinders establishing escapement goals for rebuilding (i.e., target reference points). This shortcoming is evident in the lack of biological or statistical criteria used to set current escapement goals for most BC indicator chinook stocks, which were established prior to 1985 by "doubling the average escapement observed between 1979-1982."

(CTC 1999). The following rationale is given (CTC 1999, p. 37):

> "The doubling was based on the premise that Canadian chinook stocks were over-fished and that doubling the escapements would still be less than the optimal escapement estimated for the aggregate of all Canadian chinook populations."

The specification of limit reference points is also hindered by insufficient data. Limit reference points indicate a dangerous condition that managers are attempting to avoid. However, the Agreement does not define any limit reference point in terms of the specific objective of maintaining genetic and ecological diversity, in part due to the lack of defined ESUs. Instead, the Agreement defines a more general reference point that is used to trigger additional reductions in target catches. As discussed in Chapter 5, that reference point is the "lower bound" on the escapement.

Recall that this "lower bound" is currently defined in the Agreement as the escapement at which the sustainable harvest is reduced by more than 15% from the MSY level. Given the difficulty of defining this escapement due to lack of data, this is worrisome. Scientists should be cautious about setting these "lower bounds," partly based on recent trends in escapement indices, rather than by independent biological or conservation-oriented criteria. Placing such ad hoc lower bounds on escapement goals that are already imprecisely defined seems highly risky from a conservation perspective. For the WCVI and Upper Georgia Strait stock groups, for example, recent escapements in four of their Statistical Areas (11, 12, 23, and 24 — representing twenty-three escapement sites) are just 20% of 1950-70 averages. It is unclear whether current escapement goals or their future "lower bounds" will be satisfactory from a conservation/biodiversity perspective, or whether they will, instead, reflect an already reduced or "shifted" baseline for reference (PFRCC 1999b, p. 99).

Recommendation # 5:
We recommend that DFO strongly support further efforts to define appropriate* limit reference points *(i.e., conditions to be avoided) for management and conservation of chinook and coho salmon.

Recommendation # 6:
Given the potential problems associated with indicator stocks, we strongly recommend that* target reference points *in the form of escapement goals, or other measures of rebuilding, be defined in terms that adequately reflect the variability in productivity and abundances among groups of stocks.

Recommendation # 7:
We also recommend that a significant portion of the $140 million fund under the Agreement be put into collecting more extensive and reliable data for wild stocks, especially those currently or potentially at risk, with an emphasis toward better estimation of target and limit reference points.

C. Rules to Adjust Target Catch

To meet conservation objectives, it is critical that a management system has pre-defined rules for setting exploitation rates that promote rebuilding of depressed stocks or sustain escapements when environmental conditions are unfavorable. For complex management systems, like those for chinook and coho salmon, a comprehensive model is required to establish appropriate rules. Such a model must adequately depict relationships between management regulations and anticipated exploitation rates

on stocks, so that harvest rules in each fishery can be set to achieve the escapement objectives of individual stocks.

It is commendable that the Agreement establishes some pre-defined rules for how catch ceilings in AABM fisheries for chinook will be set. Furthermore, it is clear that the PSC Chinook Model was instrumental in developing these rules, and that this model will be the basis for pre-season planning and post-season evaluation of the AABM and ISBM fisheries. We strongly encourage the continued development and application of the PSC Chinook Model, as noted in our recommendations below. It appears, for example, that the lack of detail in the Agreement for coho salmon may be due to the fact that a comprehensive, coast-wide model for coho has yet to be developed.

As noted earlier, there are two key parts to the AABM rules for chinook salmon (see Chapter 5). The first is a relationship for a given region between the annual target catch and an index of abundance of salmon. The second is a complex set of rules for reducing those target catches (called "adjustments" below) when certain criteria are met that reflect low spawner abundances.

In our evaluation of these rules, the key questions are addressed: (1) Do the rules provide for adequate protection against further declines of already depressed stocks? (2) Do the rules provide adequate potential for those stocks to rebuild? In the following sections, we first provide a qualitative assessment of these rules, and then use a simple simulation model for several BC chinook stock groups to further evaluate the AABM rules.

Qualitative assessment of AABM rules for chinook

Several aspects of the AABM rules are worrisome from the standpoint of Canadian conservation concerns. First, it is unclear whether the rules will allow for rebuilding of depressed BC chinook populations, such as those of the North/Central (NC), Upper Georgia Strait (UGS) and West Coast Vancouver Island (WCVI) stock groups. From 1985-96, approximately 60-75% of fish harvested from these stock groups were intercepted in the AABM fisheries, in particular, SEAK and NBC (values estimated from PSC Chinook Model estimates of catch and proportions of total mortality by fishery; CTC 1997). Thus, the ability of managers to meet escapement goals for these stock groups, for example, will depend largely on their ability to control AABM harvests. As noted on p. 13 of the Agreement, the AABM catch rate will be a function of "... either a pre-season forecast or an in-season estimate of abundance, and the application of a desired harvest rate index expressed as a proportion of the 1979-82 base period."

We used data for the "abundance indices" (troll component) of each AABM fishery, as estimated by the PSC Chinook Model (CTC 1997), to compute the Agreement's catch targets that would have been used in years 1979-96. These catch targets are compared to estimates of *actual* 1979-96 catches for each AABM fishery in Fig. 5. Those estimates of actual catch are based on PSC Chinook Model estimates (CTC 1997) and an assumption that Queen Charlotte Islands sport catch comprises 60% of the total sport catch in central and northern BC (B. Riddell, Canadian Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo,

Figure 5

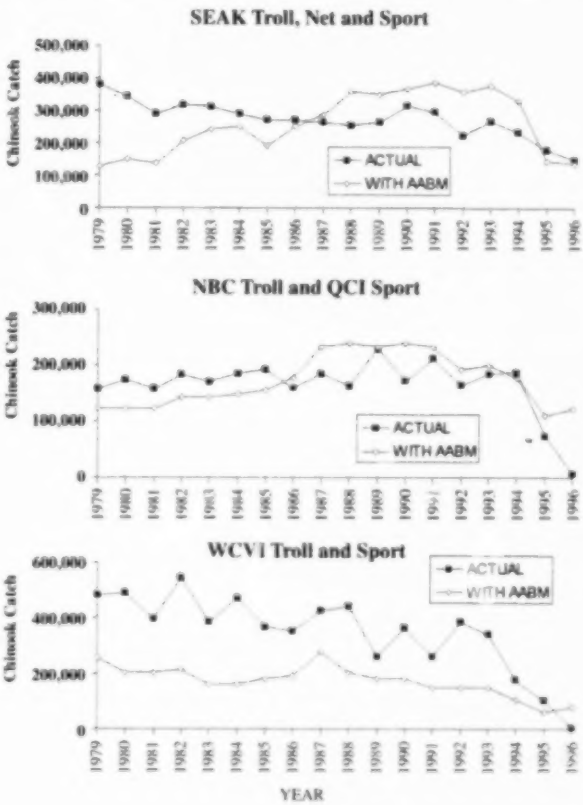


***Figure 5:** Comparison of estimated actual historical chinook catches in each of the three AABM fisheries with target catches that would have existed if 1999 AABM rules had been applied to abundance indices reported for past years in each area.*

BC, personal communication). *Relative to the 1979-82 base period*, the new rules for AABM fisheries appear to constitute reductions in proportional harvest rates of roughly 50% for SEAK, 25% for NBC, and 55% for WCVI (Fig. 5). However, from 1985-96, actual AABM harvest rates declined on average relative to the base period, in particular those of NBC and SEAK (see CTC 1997). As a result, for the 1985-95 abundance indices, the target catches specified in the Agreement represent, on average, a 45% reduction from actual catch for WCVI (mostly US chinook), a 17% increase for NBC, and a 20% increase for SEAK. (For Fig. 5, note that 1996 data were excluded from these averages due to severe catch restrictions for NBC and WCVI in that year). In other words, if the target-catch rules in the Agreement had been used in 1985-95, it appears that proportional harvest rates for NBC and SEAK would have been 17% and 20% higher on average, respectively.

Thus, because much of the overall harvest of the NC, UGS, and WCVI stock groups occurs in these two fisheries, it is unclear whether proportional harvest rates for these stock groups will differ significantly under the Agreement in comparison to the 1985-95 period. Specifically, if survival rates and abundance indices in the next decade are similar to those of 1985-95, we might expect higher harvest rates and lower escapement levels for these stock groups *unless* large reductions in harvest rates of ISBM fisheries occur. This is of some concern given that the UGS and WCVI stock groups have been well below their escapement goals in recent years.

A second concern is that the proportional harvest rates specified for AABM fisheries decrease very little as the aggregate abundance decreases (Figs. 3B-D). In fact, for SEAK, the relative harvest rate *increases* as the abundance index decreases below 1.0 (Fig. 3B). In general, we would expect abundances to be low when stocks are depressed and/or survival rates are poor. In that case, harvest rates should be reduced dramatically to ensure that escapement goals are met. This concern is especially relevant to AABM more *proactive* fisheries because they harvest many stocks, some of which are undoubtedly more productive than others. The relatively high harvest rates at low abundances (Fig. 3B) raise serious concerns about the ability of low-productivity stocks to maintain themselves during periods of unfavourable environmental conditions. In addition, the qualitative shape of the relative proportional exploitation rates does not reflect the correct shape even if stocks were at higher abundance and were being managed to meet the MSY objective that the Agreement mentions frequently. If a fixed-escapement policy aimed at achieving MSY applied, then the proportional exploitation rate should follow the general shape shown in Fig. 6. Even though we do not know the absolute scale for relative proportional harvest rates in Fig. 3B, which reflects the AABM rules, it is clear that those exploitation rates do not decrease rapidly enough with decreasing abundance to conform to a MSY objective as the abundance index decreases. They would have to decrease even more for any given *conservation* objective.

Furthermore, the AABM harvest rules may prevent recovery of some natural stocks if enhancement of other stocks leads to an increase in the aggregate abundance index and, hence, a higher target catch and proportional harvest rate. This may occur in the SEAK and NBC fisheries, for example, where hatchery stocks, such as Robertson Creek, can comprise a major portion of the available abundance (CTC 1997). However, the Agreement does not mention the problem that enhancement often leads to higher proportional harvest rates on stocks in mixed-stock fisheries which could cause a serious decline in less productive sub-stocks in the area, as was noted in PFRCC (1999, p. 24).

The two concerns raised above point out potential shortcomings of the relationships between target catches and abundance index in AABM fisheries. However, to its credit, the Agreement does specify rules for further reducing catch targets when escapement indicators of stock

Figure 6

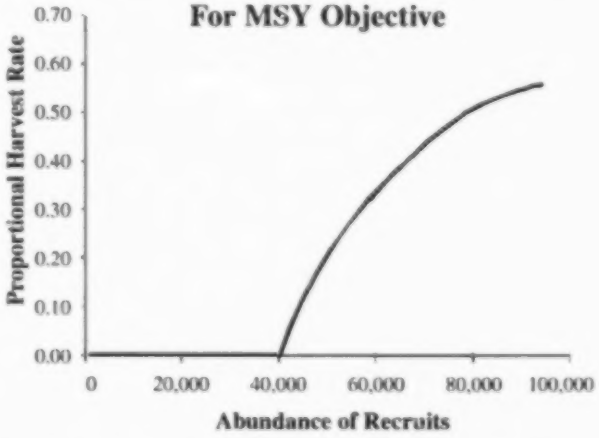


***Figure 6:** The optimal relationship between proportion of adult salmon recruits harvested and abundance of recruits to meet an objective of maximizing sustainable yield (MSY).*

groups decline below acceptable levels. Nevertheless, our third concern is that (1) the way these adjustments are triggered may cause them to occur infrequently, even when they are needed, and (2) when they do occur, the adjustments may be insufficient to promote rebuilding or prevent worrisome declines in escapements. For example, the Agreement's rules are such that, if the criterion of crossing below the lower bound of escapement is met by only one stock *group*, *no* adjustments will be made. Likewise, the escapement indicator for one *stock* (e.g., Skeena) might decline precipitously, yet the stock *group* of which it is one component (e.g., NC stock group) might not meet the criterion for further reduction in harvests because two indicator stocks must both fall below their "lower bounds" simultaneously to meet that criterion. Moreover, it is easy to conceive of situations where the adjustments of 10%, 20%, or even 30% reductions in catch specified in the Agreement would do little to prevent serious declines in escapements of multiple stock groups, let alone rebuild them. These concerns are discussed in more detail below.

A final general concern is that estimates of the abundance index for a given AABM fishery may be highly uncertain and, thus, the actual harvest rate may deviate considerably from the desired value. This is addressed in more detail in Chapter 6, Section E.

To address these shortcomings, we recommend below several analyses for the Chinook and Coho Technical Committees and certain changes to the Agreement.

Simulations of AABM rules for chinook

We used a stochastic simulation model to assess the implications of the AABM rules for escapement levels of the North Coast (NC), Upper Georgia Strait (UGS), and West Coast Vancouver Island (WCVI) chinook stock groups. As noted above, a high proportion (e.g., 60-75%) of the total harvests of these stock groups occurs in the AABM fisheries, in particular SEAK and NBC. Although this model represents a very simple depiction of these chinook populations and the fisheries that intercept them, our analyses clearly illustrate some key shortcomings of the AABM rules without the need to model the true complexities of the system.

Details of the methods we used are provided in Appendix 2. In brief, we simulated escapement levels for each stock group over a 15-year period under different assumptions about future survival rates (i.e., changes in average recruits per spawner). Harvest rates for each stock group were calculated for the three AABM fisheries (SEAK, NBC, and WCVI) as well as a fourth fishery representing harvests to ISBM fisheries (all other fisheries). Baseline parameters for stock-recruit relationships and proportional harvest rates were computed using data from 1985-95, and initial escapement levels for the NC, UGS, and WCVI stock groups were set at 100%, 50%, and 50% of their escapement goals, respectively, which is consistent with recent data (CTC 1999). Finally, we assumed that the "lower bound" of the escapement range, which "triggers" the adjustments to AABM and ISBM catches, was equal to 50% of the escapement goal (see Chapter 4 and Chapter 6, Section B for more details).

Results

There were two key results of our analysis. First, large increases in average recruits per spawner were needed for the UGS and WCVI stock groups to rebuild their escapements under the AABM regime. Fig. 7 shows average escapements for each stock group after 15 years, both with and without the "adjustments" made when escapement levels fall below "lower bounds" as described above. These average escapements, expressed in terms of percent of escapement goal, are shown for different assumptions about future changes in recruits per spawner (e.g., "-20%" means a 20% reduction in average recruits per spawner, R/S, from the baseline condition). Thus, for the baseline case (BL), the corresponding escapement levels represent our "best guess" at what the average escapements will be under the AABM regime in 15 years. Here, we estimate that there will be little increase in UGS and WCVI escapements, which were initialized at 50% of the escapement goal. In fact, to achieve the escapement goals for these two stock groups, about a 30% increase in average recruits per spawner was required (Fig. 7).

Of course, these projections for escapement levels are *highly speculative*. For example, we could only derive crude estimates of the proportion of each stock group that would be intercepted in a given AABM fishery under the rules of the Agreement (Appendix 2). Our baseline estimates of total harvest rate (i.e., with no "adjustments")

for the NC, UGS and WCVI stock groups were 0.40, 0.64, and 0.49, respectively. These are very similar to the averages observed over brood years 1981-91 (see Appendix 2), and it is possible that we overestimated the harvest rates expected under the Agreement. Nevertheless, it is clear that if recent trends in survival rates continue (i.e., our baseline case), significant reductions in proportional harvest rates will be required for stock groups such as UGS and WCVI to rebuild appreciably. As discussed previously, there is little evidence to suggest that such reductions in harvest rates will be achieved with high probability under the Agreement, largely because we expect proportional harvest rates for NBC and SEAK to increase on average relative to 1985-95. In addition, although ISBM harvest rates could be reduced by much more than the 36.5% we used in our baseline simulations to reflect the Agreement (see Appendix 2), as discussed below, the benefits may be limited, because the majority of harvest occurs in the AABM fisheries for these stock groups.

Furthermore, while a much more comprehensive model of the fisheries is required to base confidence in our estimates of escapement levels, we found that these results and those discussed below were quite insensitive to the following assumptions. First, final escapement levels changed little when the means of the abundance indices for each AABM fishery were reduced. For example, when the baseline means (i.e., means for 1985-95; Appendix 2) were reduced by 50%, the overall harvest rate for each stock declined by only 8% on average. Consequently, escapements increased by between 9% (for NC) and 22% (for UGS) on average compared to Fig. 7. Second, escapement levels were also fairly insensitive to the degree of autocorrelation in, or covariation among, the productivities of the stock groups. Although increasing autocorrelation (e.g., from 0.5 to 0.7) and covariation (e.g., from zero to 0.5) increased the frequency of "adjustments" to AABM and ISBM catch (as discussed below), the additional adjustments resulted in only slight increases in escapement levels. In addition, adding stochastic variation to exploitation rates (which would be expected due to year-to-year variation in the distribution of fish and variation in control of fishing effort) also had little effect on escapement levels.

The second key result, which is of far greater concern from a conservation perspective, was that the "adjustment rules" for reducing target catches in the AABM fisheries were *not* effective at either preventing serious declines in escapements or promoting rebuilding of depressed stocks. There were two reasons for this: (1) the criteria required for an adjustment to occur were often infrequently met, and (2) when the criteria were met, the reductions in AABM harvests were insufficient.

In our baseline simulations, we assumed that *all the other stock groups* contributing to the three AABM fisheries maintained escapements above their respective lower bounds. Thus, reductions to AABM catches were based on the proportion of years in which the escapements of the NC, WCVI, and UGS stock groups were below their lower bounds (50% of goal) for two consecutive years. Under the baseline (BL) recruits per spawner, this

Figure 7

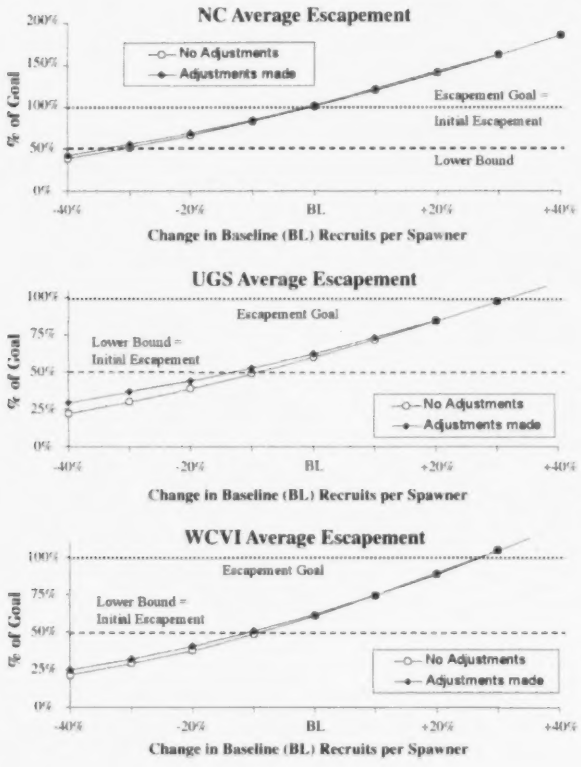


Figure 7: Results of simulations of spawner abundance for North/Central (NC) BC chinook, Upper Georgia Strait (UGS) chinook, and West Coast Vancouver Island (WCVI) fall chinook stock groups. AABM harvest rules applied in all cases, except "no adjustments" refers to not triggering additional reductions in target catches when escapements dropped too low.

criterion was rarely met for NC, and roughly 25-30% of the time for both UGS and WCVI (Fig. 8A). However, for the SEAK and NBC fisheries, catch was reduced by 10% (when two stock groups simultaneously met the criterion) in only 8% of years in the baseline conditions, while 20% reductions (requiring all three stock groups to be low) never occurred (Fig. 8B). For a given stock group's ISBM fishery, we assumed that a 10% reduction in catch occurred whenever that stock group met the criterion (Fig. 8A).

The net effect of these "adjustments" to AABM and ISBM catches was minimal. In the baseline case (BL), the average reduction in the overall proportional harvest rate of each stock group was roughly 1% (Fig. 9), and as a result, escapements increased very little in comparison to having *no* adjustments at all in response to low escapements (Fig. 7). When we reduced the average R/S of each stock to simulate decreasing marine survival rate, for instance, the adjustments to catches occurred much more frequently, but they did little to prevent UGS or WCVI escapements from declining well below their lower bounds (Fig. 7). For example, when R/S was reduced by 40%, the NC stock group met the criterion of two consecutive escapements below the lower bound in 54% of years, while both UGS and WCVI met the criterion over 80% of the time (Fig. 8A). As a result, reductions to AABM catches of 10% and 20% each occurred in 41% of years (Fig. 8B). However, this translated into only a 10-12% reduction in the overall proportional harvest rate for each stock group (Fig. 9). Thus, the frequent adjustments did little to prevent UGS and WCVI escapements from declining from 50% to just 25% of their escapement goals (Fig. 7).

We repeated these analyses under the assumption that one additional stock group (other than NC, UGS, and WCVI) met the adjustment criterion in each AABM fishery and in all years. This reflected an "optimistic" case

Figure 8A: Proportion of Years in which Two Consecutive Escapement below Lower Bound (50% of Goal)

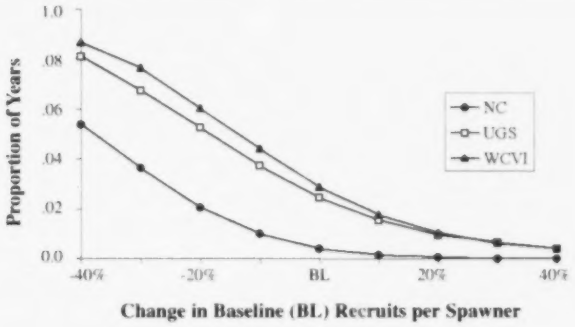


***Figure 8A**: Proportion of years in which chinook escapements were below their "lower bound" for triggering adjustments to target catch.*

Figure 8B: Proportion of Years in which AABM Catch was Adjusted

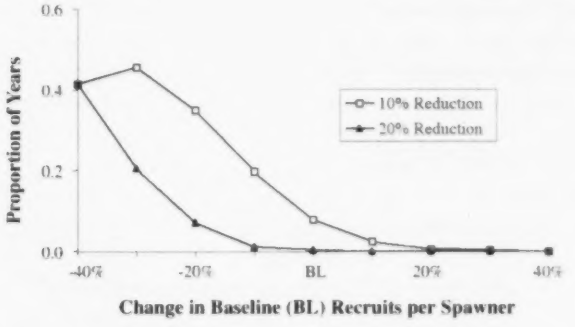
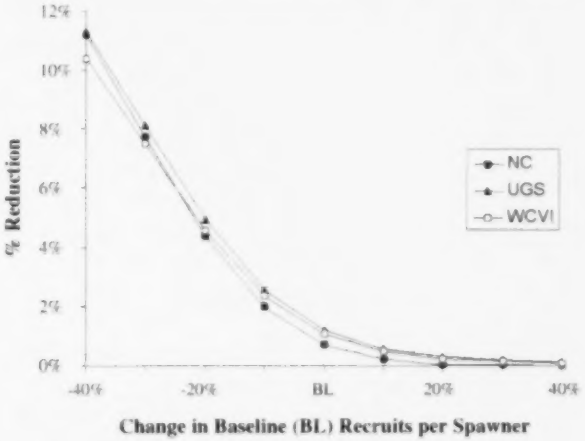


***Figure 8B**: Proportion of years in which AABM catch was adjusted either by 10% (when two escapement stock groups were below their lower bound) or 20% (when three stock groups were too low).*

Figure 9: % Reduction in Average Proportional Exploitation Rates due to "Adjustments" in AABM and ISBM Catch



from a conservation point of view because adjustments occurred more frequently and were larger. However, the corresponding changes in average escapements and harvest rates were again minimal. We, therefore, examined three additional scenarios, each "optimistically" assuming again that *one additional stock group* always met the adjustment criterion, to see how escapement levels would respond to more extreme reductions in catch than specified in the Agreement:

a) In addition to the baseline AABM rules, when a given stock group met the criterion, its ISBM fishery was closed (i.e., a 100% reduction in ISBM catch).

b) AABM reductions were increased from 10, 20, and 30% (when two, three or four stock groups met the criterion, respectively) to 10, 25, and 50%.

c) AABM reductions were increased to 25, 50, and 100% (when two, three or four stock groups met the criterion, respectively).

Results for each scenario are shown in Fig. 10 for the UGS stock group, for which the benefits of the "adjustment rules" were the largest (i.e., the "best-case" stock group). Closing the ISBM fishery each time UGS met the adjustment criterion (e.g., Fig. 8A) improved escapement levels compared to the baseline AABM rules, though this effect was limited because the majority of harvests were assumed to occur in AABM fisheries (Fig. 10A). The largest improvements occurred when reductions in AABM catch of 25, 50, and 100% were used. This scenario resulted in a 7% reduction in harvest rates under baseline (BL) recruits per spawner (Fig. 10B), which allowed escapements to increase to 73% of the goal over the 15-year period (Fig. 10A). Moreover, when R/S was reduced by 40%, harvest rates were reduced by 32%, which produced escapements at 48% of the goal (Fig. 10).

Figure 10A

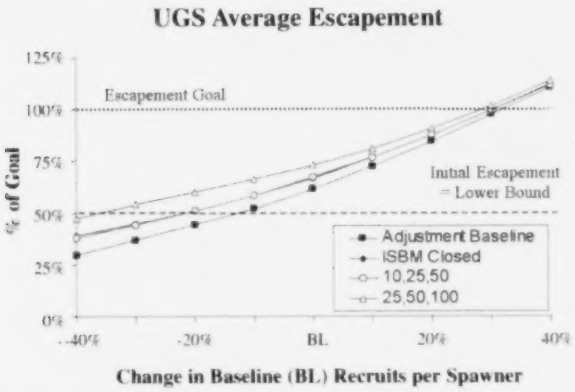


***Figure 10A**: Same as Figure 7A, for simulations of Upper Georgia Strait (UGS) chinook, except more restrictive harvesting scenarios used than specified in the AABM rules.*

Figure 10B: % Reduction in UGS Average Exploitation Rates due to "Adjustments" to AABM and ISBM Catch

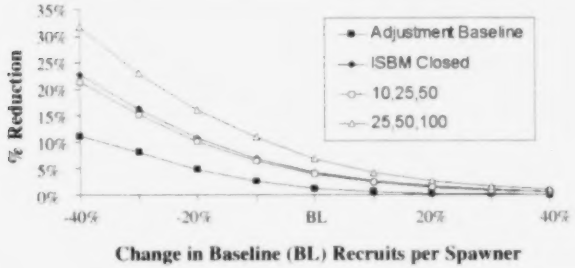


***Figure 10B**: Same as Figure 9, except only for simulations of Upper Georgia Strait chinook and for more restrictive harvesting scenarios than in AABM rules.*

Mixed-stock fisheries

As discussed previously, mixed-stock fisheries pose a particular concern for conservation objectives when they intercept salmon stocks with varying productivities (different levels of recruits per spawner). For a given exploitation rate, subtle differences in productivity among stocks can lead to very different trajectories for spawner abundances. This is clearly illustrated in Fig. 7 for the "no adjustment" curves of each stock group. In the previous section, we discussed changes in average recruits per spawner along the X-axis in the context of the possible environmental conditions the indicator stocks might face in the future. However, one can also think of these as different productivities exhibited by stocks within or between regions. For UGS, for example, the baseline Ricker "a" was 1.28 (Appendix 2), which implies that 3.6 (i.e., exp[a]) recruits are produced per spawner at low spawner abundances (where there is little density dependence). Thus, the range of -40% to +40% in Fig. 7B represents a range of exp[a] values from 2.2 to 5.0. For the baseline value, escapements increased slightly from their initial level (50% of goal), while for a stock with

exp[*a*] of 2.2 (i.e., equivalent to a -40% change in recruits per spawner), the escapement level declined to just 22% of the goal. This raises a question: Are the indicator stocks representative of the stock group in general? If they are more productive on average, then clearly the situation can exist where the indicator stocks are rebuilding or are at their goal, while other, less productive stocks are declining or remaining at escapement levels that may be well below tolerable ranges from a conservation perspective.

Discussion

The results of our simulation analyses illustrate some very basic relationships between escapement levels, harvest rates, and changes in survival rates. In general, to maintain constant escapement levels as survival rates decline, exploitation rates must be reduced by a similar extent. Under the Agreement, the adjustment rules for AABM fisheries are not sufficient to prevent escapements of major BC stock groups from declining dramatically if survival rates decline (e.g., UGS and WCVI). Furthermore, the rules do not appear to promote significant rebuilding of these stock groups under conditions where future survival rates are similar to those of the recent past.

The apparent inadequacy of the "adjustment" rules is further demonstrated in the following example. Suppose that *all* 20 indicator stocks for the eight stock groups listed under SEAK were, on average, at the lower bound for their escapement goal. Thus, due to random variation, we would expect that 50% of these would be below their lower bound in any given year. In our view, this represents a situation where *dramatic* rebuilding efforts should be implemented. However, when we simulated this situation using the criteria required for adjusting SEAK catches, we found that catch was reduced by only 6% on average when the escapement indices contained no autocorrelation, or about a 15% reduction when they were moderately autocorrelated (each with lag-1 autocorrelation of 0.7). It seems very unlikely that such reductions would promote rebuilding in a timely fashion and it, therefore, seems critical that more restrictive measures be taken when necessary.

In addition, although the Agreement already contains a *reactive* component, it needs more appropriate indicators to trigger pre-defined management actions once the chance of maintaining some measure of biodiversity becomes unacceptably low. Further research must also be done to identify appropriate target catches for given values of the abundance index to create a low probability that some specified number of ESUs will become a significant conservation concern in the first place (i.e., the *proactive* component). If the proactive component is sufficient, the reactive component will rarely be required.

Recommendation # 8:
We strongly recommend that* reactive *rules for adjusting AABM catches should be based on thorough simulation analyses that:
(1) explicitly state the objectives of adjustments in terms of either maintaining a stock group's escapement levels or rebuilding them within a given time frame, and
(2) assume a range of plausible scenarios for future survival rates.

Recommendation # 9:
We recommend that more* proactive *stochastic simulation models be used to identify target catches (i.e., to minimize the chance of crossing some yet-to-be-defined limit reference point, or low abundance, that is of concern for conservation for certain stocks, while still maintaining reasonable catch levels).

Qualitative Assessment of AABM Rules for Coho

Chapter five of the Agreement is laudable for supporting the continuation of the joint Canada-US Coho Technical Committee (and the chinook committee as well). These committees provide critical data bases, analyses, and recommendations needed by fishery managers.

Like the chinook section of the Agreement, this coho section also emphasizes a maximum sustainable harvest goal which, as noted above, has severe drawbacks from a conservation point of view. However, to its credit, in the case of the coho stocks shared by Washington and southern BC fisheries, the Agreement recognizes (bottom of p. 31)

that exploitation rates of wild coho stocks should be constrained: "...to produce maximum sustainable harvests over the long term while maintaining the genetic and ecological diversity of the component populations." This is the first mention of biological diversity of coho stocks in the Agreement and, while this statement is logical, the rest of the Agreement gives no guidance on how to achieve this difficult joint objective. Doing so would presumably involve managers making a choice between different situations, some with a high harvest and high probability of low-abundance, and others with a lower harvest but less probability of low-abundance. The lack of clear definition in the Agreement of the ecological implications of such trade-offs is understandable. Little is known about the population dynamics of coho stocks at low abundance. Canadian management agencies should, therefore, place priority on identifying the implications of various probabilities of having one or more coho stocks in an area fall below a given abundance.

In general, this coho section for Washington/Southern BC is much less thoroughly worked out than the previous chinook section. The ideas are certainly heading in the right direction in the sense that the goal is to eventually develop pre-defined harvest rules and geographical management units, and to apply management regulations that will provide some harvest, while maintaining genetic and ecological diversity. However, the details concerning indices of abundance, methods of interpreting data, state-dependent harvest rules, management objectives, etc. were to be worked out by the Coho Technical Committee. Discussion of the coho stocks in the Northern BC/Southeast Alaska region is even more limited (three lines on page 35 of the Agreement, and a two-page Attachment B; the latter mentions only MSY escapement goals, not conservation or rebuilding goals). However, in both cases, the intention is to develop for coho the same type of pre-specified AABM rules as described above for chinook. Our general findings for chinook are, therefore, equally applicable to coho.

The current state of knowledge concerning several key concepts related to conservation of coho stocks is limited. Therefore, it is commendable that the Agreement states (p. 36) that the joint Canada-US Coho Technical Committee shall conduct workshops or working sessions on important topics, including: "...methods of incorporating risk in protection of genetic and ecological diversity; and standards for emerging methods for estimating stock composition (DNA)." The coho committee should develop a regional coho model to provide a consistent means of evaluating the cumulative impact of US and Canadian fisheries on key management units and stocks of conservation concern. It is not clear whether this will simply be an extension of the existing coho model used by the committee or a new model.

D. Effective Monitoring and Control of Exploitation Rates

Effective monitoring and control of exploitation rates is essential in achieving conservation objectives. Yet, this is a serious challenge for managers of wild chinook and coho stocks. Considerable catch of these fish is taken in mixed-stock fisheries, and exploitation rates for many small natural stocks are only estimated from exploitation rates on coded-wire-tagged hatchery stocks that are harvested in those same fisheries. This extrapolation to other stocks requires numerous assumptions, but at present there is no alternative.

The Agreement's pre-defined rules constrain the change that can occur to harvest; even when escapement indices are weak in all stock groups, AABM target catches are reduced by at most 30%. Clearly, this is insufficient when serious problems arise. While paragraphs 9f and 9g in Chapter 3 permit *requests* for more extreme reductions in harvests, they do not contain pre-agreed rules or frameworks for evaluating such requests, let alone a requirement to implement such reductions.

Recommendation # 10:
Management agencies should be encouraged to continue moving towards more selective, less mixed-stock fisheries. In the meantime, the Agreement should be revised to require more severe reductions in target catches in extreme situations.

Another conservation issue is the apparently weak incentive for not exceeding catch targets outside of any country's jurisdiction. For instance, Chapter 1 on transboundary rivers covers those that have main spawning grounds in northern BC and cross into Alaska as they flow to the sea (e.g., the Stikine and Taku). This chapter contains provisions regarding either Canada or the US (i.e., the "Parties") taking more than their share of the harvests. For instance, it states on page 2: "The Parties

agree that if catch allocations set out for transboundary river salmon are not attained due to management actions by either Party in any one year, compensatory adjustment shall be made in subsequent years." However, the Agreement does not specify a time by which such a compensatory adjustment should be made and, in fact, the last sentence of paragraph 4 on page 4 implies that there is no incentive to make that adjustment. It states: "At the end of the Chapter period [i.e., in the year 2008], cumulative overages or underages will be carried forward to the next Chapter period." Thus, control of overharvesting apparently depends on good will. Again, we emphasize that we are only judging what is written down, not what might have been in verbal agreements or unwritten intentions of the negotiators and their staff.

Recommendation # 11:
While maintaining some flexibility, the Agreement should create stronger incentives to discourage exceeding target catches.

E. Harvest Rules That Take Into Account Uncertainties

Uncertainties are an unavoidable feature of salmon biology and management. Uncertainties arise from three main sources: (1) complexity of the biological and human systems being managed; (2) natural variability from year-to-year and stock-to-stock in survival, growth, reproduction and harvest rates; and (3) imperfect information (i.e., errors in estimates of escapement or in catch due to inadequate stock identification).

One important example of biological uncertainty is variability in marine survival rates. There is growing evidence that large and persistent fluctuations or trends in oceanographic conditions can occur over time at regional scales. These changes can drastically affect productivity of salmon stocks (e.g., Peterman et al. 1998). When conditions are unfavorable, lengthy periods of depressed spawner abundances may occur, even in the absence of exploitation.

The long time lag involved in detecting such unfavorable conditions, due largely to natural variability and imperfect information, suggests that harvesting rules must be cautious when exploiting such populations. Harvest regimes must also be responsive to such conditions when they are finally detected, suggesting that periods of lengthy and extreme limits on fishing might be related to the frequency of occurrence of unfavourable conditions for marine survival. If high harvest rates are mistakenly applied to fish stocks when they are experiencing unproductive marine conditions, for example, they might push those stocks down to unsustainable escapement levels that would rarely have occurred in the absence of exploitation. In addition, this situation would greatly reduce the potential for recolonization or rapid rebuilding of stocks to productive harvestable levels. Thus, from the perspective of both conservation and harvest goals, management regimes must be responsive to broad-scale, persistent changes in fish productivity, applying extreme fishing restrictions in a timely fashion, when necessary.

Recommendation # 12:
Management agencies should be provided with sufficient funds to ensure that data can be collected on appropriate variables (e.g., marine survival rates from coded-wire-tagged hatchery chinook and coho, and escapements of low-productivity stocks that are a particular conservation concern), and that management regimes can react to those data promptly and appropriately, if conditions deteriorate for marine or freshwater survival rates of salmon.

Another source of uncertainty is implementation error, which reflects the inability of managers to perfectly control harvesting, thereby leading to variation of actual realized harvests around the targets. Implementation error exists because estimates of salmon abundance from pre-season forecasts are generally not very accurate, and revisions based on in-season estimates usually do not completely make up for such errors. This prevents accurately meeting escapement goals or target catches (e.g., Eggers and Rogers 1987; Bocking and Peterman 1988). In some

cases, catches can be larger than desired, thereby putting low-abundance stocks at extreme risk. Implementation error also creates uncertainty about actual proportional harvest rates that will occur on specific wild stocks. This suggests that harvest rules should err on the side of caution from the standpoint of a stock's abundance.

These sources of uncertainty and risk are critical from the standpoint of conservation, yet the Agreement rarely mentions these concepts. Furthermore, the Agreement frequently focuses on MSY escapement goals (or other yet-to-be defined and agreed upon goals). However, this does not reflect the growing trend worldwide, for cases where conservation is a concern, to use MSY as a "limit reference point," which is an extreme case to be avoided, rather than a desirable "target reference point" (FAO 1994). Goals of MSY escapement or MSY harvest rate are increasingly categorized as being risk prone, rather than risk averse, because of the large uncertainties that pervade analyses and control of fisheries. Specifically, MSY escapement goals for salmon presume good knowledge of the current stock abundance (i.e., recruits), excellent control over harvesting, and high quality estimates of a stock's parameter values (which require small measurement error and large variation in recorded historical abundances). However, these conditions do not hold for most wild Canadian chinook and coho stocks. Collectively, these sources of uncertainty create higher biological risks for stocks that are managed with MSY escapement goals than for those that have higher escapement goals.

To recognize these sources of uncertainty, target catches could be set by adjusting the desired catch or harvest rate by some arbitrarily chosen "safety factor," but it is usually not clear whether the result is safe enough or unnecessarily restrictive on fishing. Another approach is to determine quantitatively how large a "safety factor" is required, based on some stochastic simulation model that quantifies uncertainties. We suggest the latter approach because it is more likely to identify appropriate harvesting rules. The AABM rules apparently were designed to impose such a "safety factor" — they reduce target catch as the abundance index decreases, and they further reduce that target if spawner abundances drop too low. Regardless, our analyses described above suggest that they do not provide a large enough "safety factor" from the standpoint of conservation.

Recommendation # 13:

We strongly recommend that the Agreement's rules be modified to reflect large uncertainties and variability, by adequately reducing target catches for a given abundance. In particular, those rules should reflect the lengthy period that it takes to detect major changes in oceanographic conditions and resulting changes in salmon productivity.

Recommendation # 14:

We also strongly recommend that the Chinook and Coho Technical Committees carry out extensive simulations (taking uncertainties into account) to identify the relative merits of different reference points and harvest rules, and the resulting trade-offs between biological and economic risks.

7. Comparison of the Agreement with Other International Documents

The 1999 Canada-US Agreement under the *Pacific Salmon Treaty* was negotiated during the period when worldwide sentiment for more conservative fisheries management was just emerging (e.g., FAO 1995a,b; United Nations 1995; Richards and Maguire 1998; de Young et al. 1999). We cannot necessarily expect, however, that the Agreement would reflect all of those concerns. Nevertheless, it is worth looking at the documents just cited to help point towards future improvements to the 1999 Canada-US Agreement, as well as towards characteristics that the Chinook and Coho Technical Committees should put into their plans for implementing the Agreement.

It is extremely significant that the 1999 Canada-US Agreement rarely mentions the concepts of uncertainty and risk, given their predominance in the above major international fisheries agreements and documents. In fact, the word "uncertain" only appears once in the 1999 Canada-US Agreement (and then it only refers to the very narrow topic of incidental mortality, e.g., interceptions or bycatch). Furthermore, "risk" only appears twice (p. 26 and 36), and no details are given for measuring it. This infrequency suggests that many widely recognized effects of uncertainties and resulting biological risks will not necessarily be taken into account by either the AABM rules or other aspects of the management framework that are yet to be defined by the Chinook and Coho Technical Committees. This situation is surprising, given that formal assessment of risks is a standard part of fishery stock assessment procedures in the US National Marine Fisheries Service, as well as the precautionary approach that DFO supports. The US and Canada also agreed to apply the precautionary approach in Article 6.1 of the 1995 United Nations Agreement on Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (United Nations 1995), which was signed by both countries. We acknowledge that, while both Canada and the US signed the UN agreement in December 1995, it has not yet come into force because not enough nations have yet ratified it. Nevertheless, we would expect that negotiations between Canada and the US would be consistent with that UN agreement. The pre-specified AABM rules reflect some of the UN agreement's recommendations but many critical ones are omitted.

For example, the FAO (1995a) document on the "Precautionary Approach to Capture Fisheries" states that "...where the likely impact of resource use is uncertain, priority should be given [particularly by management agencies and industry] to conserving the productive capacity of the resource" (FAO 1995a, paragraph 6d). In other words, harvest rates should be reduced from what would be estimated as ideal if perfect information were available. However, the 1999 Canada-US Agreement only reflects this viewpoint in one place (p. 26), where the imprecision of management regulations to achieve a goal is recognized as a reason to alter a harvest regime, but no details are provided.

The FAO (1995a) document also states that "...when there is a good year class, give priority to using the recruits to rebuild the [spawning] stock rather than increasing the allowable harvest" (FAO 1995a, paragraph 48d). In other words, where harvests have been reduced or eliminated to allow a stock to rebuild, strong restrictions on harvests should be maintained for some time, even after increases in abundance begin to be observed, in order to increase the chance that the stock will rebuild. Instead, the 1999 Agreement's target chinook catch increases immediately with increasing estimated abundance. This will slow or possibly prevent rebuilding.

Similarly, the 1999 Agreement does not reflect Article 6.2 of the 1995 UN Agreement that points out: "States shall be more cautious when information is uncertain, unreliable, or inadequate." In fact, the AABM rules set out specific relationships between an allowable harvest and an abundance index. But there is no indication of how those relationships should be changed if data are more uncertain, nor does it state whether those relationships were derived to reflect uncertainty about estimates of abundance and lack of perfect control over harvests. Future analyses of appropriate harvest rules should take those uncertainties into account by adjusting harvest rates by an appropriate "safety margin."

There also does not appear to be enough flexibility in the 1999 Agreement to deal quickly with extreme situations. This is addressed in Article 6.7 of the 1995 UN Agreement: "If a natural phenomenon has a significant adverse impact on the status of straddling fish stocks or highly migratory fish stocks, States shall adopt conservation and management measures on an emergency basis." That section went on to refer to emergency response to effects of fishing. In British Columbia, we are well aware of the large effect that ocean conditions have on survival rates of Pacific salmon, and that those conditions are quite variable and perhaps trended over time. This means that, to conserve low-abundance chinook and coho stocks, harvest regulations must be quickly and sufficiently responsive to adverse conditions. The 1999 Agreement's adjustments to target catches when escapement gets too low are a method for such a response for chinook salmon. While it is rapid, it does not appear to allow sufficient flexibility to reduce harvest rates to extremely low levels (including zero) if severe ocean conditions occur in the future — at most, the method reduces the target catch by only 30%. Therefore, there does not appear to be adequate flexibility in harvest rates.

Another quote from FAO (1995a, paragraph 48g) is appropriate here: "...do not use artificial propagation as a substitute for the precautionary measures listed above." This concept should be inserted into the 1999 Agreement where it first proposes to use enhancement from hatcheries in Annex IV, Chapter one on "Transboundary Rivers." This would reflect the concerns mentioned earlier in this report about the potential adverse effects of enhancement on unproductive stocks.

Finally, the 1999 Agreement does not fully reflect widespread usage of reference points, which are mentioned in the 1995 UN Agreement. For instance, it is stated in Annex II: "Precautionary reference points should be stock-specific to account for the reproductive capacity...and major sources of uncertainty." For reducing target catches, the Agreement specifies as a general reference point for taking action (reflecting that some unspecified "limit" reference point is being approached) the "lower bound" of escapement for an aggregate of spawner abundances in two consecutive years for at least two stock groups. While this reference point is not stock-specific for reasons of limited data as noted previously, we think that the definition of that reference point is so restrictive that it is not very likely to achieve its goal of halting declines in abundance and rebuilding stocks. Furthermore, that reference point does not appear to have been designed to be consistent with another statement in Annex II of the UN Agreement: "Fishery management strategies shall ensure that the risk of exceeding limit reference points is very low." The 1999 Agreement gives no indication of the condition the "lower escapement bound" reference point is attempting to avoid.

Recommendation # 15:
The Agreement should be amended, and details of implementation for coho and chinook should be written, to make the Agreement's objectives, indicator stocks, and rules for modifying target catches more consistent with the objectives and methods stated in the United Nations FAO's "Precautionary Approach to Capture Fisheries" and "Code of Conduct for Responsible Fisheries," and in the 1995 UN Agreement on Straddling Fish Stocks and Highly Migratory Fish Stocks.

In closing, the 1999 Canada-US Agreement has made positive steps forward in the management of chinook and coho salmon. Many features of the Agreement are moving management in the right direction from the viewpoint of conservation. However, there is considerable room for further improving the Agreement. In particular, we encourage the additional changes suggested by our recommendations.

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9. Appendices

APPENDIX 1 — METHODS USED TO GENERATE FIGURES 1A AND 2A

To examine past trends in salmon escapements, we selected records from the SEDS data base. For coho salmon, we used only those stream sites where 20 or more years of data were available (from 1950-97). This accounted for 737 of the 1515 sites. For chinook salmon, we selected the 241 sites with at least 15 years of data (out of a total of 531 sites). Each estimate of spawner abundance was then log-transformed, and the resulting time series for each stream site was standardized to have a mean of zero and a standard deviation of one (this created a time series of deviations [i.e., residuals] in spawner abundance from the mean for that site). By standardizing each time series, each site was given equal weighting in the following calculations. Next, for each Statistical Area (1-29), we calculated a mean residual for each year by averaging across the index sites of that Statistical Area. To ensure that each annual mean was representative of the Statistical Area, it was only computed for years in which data were available for at least 40% of the index sites of that Statistical Area. This generated 29 time series of average residuals by Statistical Area for coho salmon, and 25 time series for chinook salmon. Finally, we generated Figs. 1A and 2A by averaging across the mean residuals for each Statistical Area and year.

APPENDIX 2 — SIMULATION METHODS

This Appendix provides some details of our simulations of the AABM rules for chinook salmon. Because *stock-specific* adult recruitment (catch plus escapement) data are difficult to obtain for wild BC chinook stocks, we had to indirectly estimate parameters and initial conditions for this analysis using data from 1985-95. In addition, to estimate the proportion of each stock expected to be harvested in a given fishery, we scaled average proportions from 1985-95 to roughly reflect the proposed changes in the Agreement. We recognize that these are only crude approximations to real situations. However, our general conclusions about the effectiveness of the AABM rules are likely relatively robust to a reasonable range of assumptions about these estimates.

As defined in the Agreement on page 20, annual target catches decrease with a decreasing abundance index in a given AABM fishery: Southeast Alaska (SEAK), Northern BC (NBC), and West Coast Vancouver Island (WCVI). Those target catches are further reduced by adjustments as defined on p. 18 of the Agreement when measures of spawning escapement within a stock group fall below a "lower bound" (also see our section on "Indicators to Reflect Objectives"). We modeled these rules and their potential implications for three BC chinook stock groups: North/Central BC (NC), Upper Georgia Strait (UGS), and West Coast Vancouver Island fall chinook (WCVI). Note that for simplicity, we simulated a single population for the NC stock group to represent its three indicator stocks, which is optimistic in that it leads to adjustments occurring more frequently when escapements fall below the "lower bound."

To simulate the population dynamics of a given chinook stock group over 15 years, we used the Ricker stock-recruitment model (Ricker 1975):

$$(1) \quad R_t = S_t e^{a(1-S_t/b)+v_t},$$

where R is the recruits produced from spawners, S, that spawned in year t, e^a is the recruits per spawner at low spawner abundance, b denotes the unfished equilibrium spawner abundance, and v is a normally distributed random error term. The age structure of the adult recruits, R, was assumed to be 25% age-3, 50% age-4, and 25% age-5 fish.

We determined Ricker parameters for each stock group in the following ways (see Table App2-1 for summary). First, we assumed that the unfished equilibrium spawner abundance, b, was equal to three times the escapement goal, S^*. It can be shown that this is a rough, but reasonable expectation for an MSY escapement goal under a variety of assumptions about the Ricker a value. Next, to compute reasonable Ricker a parameters for each stock

group, it can be shown that the following equation applies:

$$(2) \quad a = \frac{\ln[1/(1-H)]}{1-S'/b},$$

where S' is the "equilibrium" spawner abundance at a given proportional exploitation rate, H. Over brood years 1981-91, the average exploitation rates (H) for the NC, UGS, and WCVI stock groups were 0.39, 0.66, and 0.52, respectively (CTC 1998). In addition, over 1985-95, average spawner abundances (S') for NC indicator stocks were roughly equal to their escapement goals ($S^{\bullet}$), and approximately $0.5S^{\bullet}$ for both UGS and WCVI (CTC 1999). Because both exploitation rates (H) and spawner abundances (S') remained roughly constant over these periods, the above values were used in the "equilibrium" equation (2) to compute Ricker a parameters (Table App2-1). Finally, for each stock group, r was modeled as a first-order autoregressive (AR(1)) process with autocorrelation coefficient $\phi_r = 0.5$ and standard deviation $\sigma_r = 0.4$ (Box et al. 1994). In our baseline simulations, we assumed that there was no covariation among the random error terms (r) of each stock group. However, in sensitivity analyses, we included such covariation using simple linear models to generate two or more correlated variables (r) with specified variances and autocorrelation (see Pyper and Peterman (1998) for details). To be consistent with recent data mentioned above, initial escapement levels for the NC, UGS, and WCVI stock groups were set at 100%, 50%, and 50% of their escapement goals ($S^{\bullet}$), respectively.

For each stock group, we simulated harvests in the three AABM fisheries (SEAK, NBC, and WCVI) and in a single ISBM fishery (individual stock-based management regime, representing harvests in all other fisheries) using the following steps. First, an Abundance Index (AI) in year t was generated for each AABM fishery using an AR(1) model. The mean, autocorrelation coefficient, and variance used for each modeled fishery were estimated using data from 1985-95 (CTC 1997) (Table App2-2). In addition, the AIs for SEAK and NBC were modeled with a correlation of 0.8, which was similar to that observed from 1985-95. For a given AABM fishery, the value of its AI in year t determined the *relative* harvest rate (Ft) to be used in that year (see Fig. 3).

Next, the proportion, P_t, of each stock group harvested in a given AABM fishery in year t was computed as:

$$(3) \quad Pt = P_0 \frac{F_t}{F_0},$$

where P_0 was the baseline proportion harvested and F_0 was the baseline *relative* harvest rate (i.e., the value that corresponded to the mean AI for 1985-95 as shown in Table App2-2). For each stock and AABM fishery, the baseline proportion harvested (P_0) was computed as:

$$(4) \quad P_0 = M \left[\sum_{1985}^{1995} \frac{C_{rules}}{C_{actual}} \right] \Big/ 11,$$

where M was the average proportion harvested over 1985-95 (CTC 1997) adjusted by the average ratio of *catch that would have occurred* for 1985-95 under the rules of the Agreement to *actual catch* for 1985-95 (see Fig. 5). Note that approximate values are used for "actual" catch based on PSC Chinook Model estimates (CTC 1997) and an assumption that Queen Charlotte Islands (QCI) sport catch constitutes 60% of the total sport catch in central and northern BC (B. Riddell, pers. comm.). For each stock group, the proportion harvested (P_0) by ISBM fisheries (including the WCVI, central and northern BC net fisheries, and central and northern sport fisheries, but excluding QCI) was computed by reducing the 1985-95 average by 36.5% to reflect the minimum reductions (relative to the base period 1979-82) stated on p. 15 of the Agreement. Note, however, that our baseline estimates of ISBM mortalities likely represent larger reductions (relative to the base period) than 36.5% because exploitation rates in many ISBM fisheries had already declined over 1985-95. In summary, values of P_0 for AABM and ISBM fisheries are estimates of the proportion of a stock that would have been harvested over 1985-95 had the catch rules in the Agreement been used (Table App2-2). If the escapements of two or more stock groups fell below their "lower bounds" (i.e., $0.5S^{\bullet}$) for two consecutive years (t-2 and t-1), then values of P_t were adjusted according to the rules on p. 18 of the Agreement.

TABLE APP2-1:

Parameters for Ricker stock-recruitment relationships. Abbreviations for stock groups are: NC=North/Central BC, UGS=Upper Georgia Strait, and WCVI=West Coast Vancouver Island. S^* denotes the escapement goal.

Stock Group	a	b	σ_V	ϕ_V	Initial Spawner Abundance	Avg. Exploitation Rate (1981-91)
NC	0.73	$3S^*$	0.4	0.5	S^*	0.39
UGS	1.28	$3S^*$	0.4	0.5	$0.5S^*$	0.66
WCVI	0.87	$3S^*$	0.4	0.5	$0.5S^*$	0.52

TABLE APP2-2:

Parameters for AABM and ISBM fisheries. Abbreviations for fishery areas are: SEAK = Southeast Alaska, NBC = Northern BC (including Queen Charlotte Is. sport), and WCVI = West Coast Vancouver Island.

Fishery	Average Abundance Index (1985-95)	F_0, Baseline Relative Harvest Rate	P_0, Baseline Proportion Harvested by Stock Group		
			NC	UGS	WCVI
SEAK	1.58	0.98	0.19	0.27	0.26
NBC	1.45	0.91	0.15	0.21	0.09
WCVI	0.79	0.87	0.00	0.00	0.05
ISBM	n/a	n/a	0.06	0.16	0.09

Notes

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